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ABSTRACT

One hundred and sixteen lesson plans for a first, second, third and fourth year electrical apprentice technical training program are presented in this manual. The lesson plans are generally organized into four steps: introducing the lesson, presenting the lessons (e.g., demonstration), student application (use of worksheets), and checking and follow-up (checking answers to worksheets). Some of the lesson topics are these: first year: tools and equipment, introduction to electricity, cable assemblies, fluorescent lighting and blueprint reading; second year: electrical systems, single phase transformers, three phase motors, sample house plans, and outlet circuiting; third year: alternating currents, power factor correction, class III installations, fundamentals of motor control, and estimating job costs; and fourth year: cable trays, cellular metal floor raceways, switchboards and panelboards, radio and television equipment, and effective foremanship. (Instructor manuals for each year--including lesson plans, information sheets, worksheets, and tests--and workbooks containing worksheets and information sheets are available in separate documents, CE 018 350-360.) (JH)

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ED160877

JOBSITE SUPERVISOR

INSTRUCTOR'S MANUAL

FOR

ELECTRICAL APPRENTICE

TECHNICAL TRAINING

BEST COPY AVAILABLE

SERIES "A"
(First Year)

SERIES "B"
(Second Year)

SERIES "C"
(Third Year)

SERIES "D"
(Fourth Year)

Revised to meet 1978 Electrical Code

PROGRAM DEVELOPMENT
DEPARTMENT OF COMMUNITY COLLEGES
RALEIGH, NORTH CAROLINA

CE 018 352

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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FOREWORD

The apprenticeship programs offered in North Carolina are important phases of the total educational program for industry in the state. The program of education for modern apprenticeship includes two distinct phases. The first phase is "on-the-job training." The student is employed by a firm in which duties are specifically assigned to enhance ones learning in the field of study. These experiences are planned and supervised so that the individuals will progress through the apprenticeship phase to that of the journeyman. The second phase of the program of education is termed "related instruction." In this phase the apprentice is provided the technical and theoretical foundation subjects that help one to learn the trade thoroughly and accurately. This portion is usually taught through evening school, but in some cases may be done through correspondence courses.

The North Carolina Department of Community Colleges, through the Program Development Section, has the responsibility for developing and making available the instructional materials that provide the learner with a sound educational program which is effective and appropriate to the method in which the materials are being utilized. The department has available these materials for the students, as well as support material for the instructor who teaches or who acts as counselor in conducting the related classes.

Roger G. Worthington

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ELECTRICAL APPRENTICESHIP TECHNICAL TRAINING

ACKNOWLEDGMENTS

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PREFACE

The Program Development Section of the Department of Community Colleges has the responsibility for making available the related instructional materials required for use in occupational programs offered by the various institutions. This responsibility is accomplished by working with advisory committees and consultants representing each of the occupations in determining the needs and in developing the materials required to meet these needs.

These information sheets and worksheets have been prepared to provide specific assignments for studying related topics necessary in the training of electrical apprentices. An effort was made to develop the schedule to follow as the apprentice progresses with training. It will also enable the apprentice to know what skills and knowledges will be required. The objective of this program is to aid the instructor and employer in providing experiences necessary to develop not only a competent worker in the electrical field, but also, a well-rounded citizen.

This workbook includes assignment sheets and information sheets for the electrical apprentice to use in searching out related information. The worksheets contain problems to solve, questions to answer diagrams to draw, and blueprints to consult. The apprentice should study the references (assigned by the instructor) before attempting to answer the questions or solve the problems.

In actual use of these lessons, instructors should feel free to modify their application of the material to conform with local needs. For example, there may be certain sections of the Code to teach because the apprentices are working with special installations. Thus, the instructor should lead a discussion on materials that applies to these situations. In other classes, the instructor may need to spend more time with the students on topics dealing with mathematics than with blueprint reading. In any event, the minimum class time for related material is 144 hours per year. It is sincerely hoped that the assignment sheets are used correctly so that apprentices can gain maximum benefits from their related studies.

JOBSITE INSTRUCTOR GUIDELINES

To the Instructor:

It is suggested that the jobsite instructor check his men's employment application or in some other way learn as much as possible about his students. Information which will prove helpful to you includes:

Name	Types of work done before
Address	Marital status
Birthplace	Children, if any
Education	Hobbies
Former employers	Likes, dislikes, etc.

- The more you know about the people you deal with, the better you are able to relate the information to be taught so they can understand the subject.

- The Jobsite Instructor's Manual and the student assignments or worksheets have been revised to update the materials. Lessons are arranged in topics to reflect the sequence of on-the-job training more closely and stress electrical installation rather than to cover electronics. The information in this Instructor's Manual is to refresh your memory and give you some sequence of material presentation which your men will be covering in their assignments. It is not intended to be a Lesson Plan but to serve to help you answer any questions which the apprentice may ask concerning the material covered in the assignment he is working on.

- The information sheets and assignments are designed to help the apprentice master the related technical materials found in the textbooks and references. Each item of every topic has not been fully covered but is representative of the material the student is expected to learn. You can be of much assistance in relating your own work experiences concerning a specific item in the lesson and show the apprentice the necessity of his mastering each step up the ladder.

- The Apprentice Trainee is required to spend a minimum of 144 hours per year in a related training program whether in a school situation or by correspondence. The material covered in a year's course has been programmed out to cover the 144 hours, and even the correspondence student will find he has spent the 144 hours in study, searching out the answers to his assignment questions, completing the various tests, and spending guidance time with you, his jobsite instructor.

- The instructor should take time to review the entire course to understand the relationship of the materials. Also, this will help in planning so the lessons will be completed in 144 hours. Jobsite

work schedules may temporarily interfere with a student's regular assignment work schedules, but the apprentice should be encouraged to make an extra effort under these circumstances to keep up his lessons and tests. Once a study habit has been set, it's easy to break, and even harder to restart again. Patience, tolerance, understanding, and an occasional "pat-on-the-back" will add much toward keeping the student learning and the apprentice doing good work on the job.

- Assignments and page references have been placed on sheets following each year's Table of Contents. These sheets can be revised easier than all the lesson sheets when textbooks are changed.

- Each apprentice should have a large three-ring notebook to keep the assignment sheets, notes, and other bits of information that he will begin to collect. Over the years, this will prove to be a valuable reference source for information he will constantly need.

- Your responsibility as the jobsite instructor is as detailed as you want to make it. You should be available to answer any questions which the apprentice may ask concerning his on-the-job training or his related technical training which he gets with his assignment sheets and tests.

- The necessary paper work between the resident instructor and the apprentice should be reviewed by you so you know his problems, accomplishments, and status of his training. His assignments and tests should be looked over to be sure he understands his assignment and is learning the material which it covers.

- When you have more than one apprentice at your job, the chances that all will be doing work on the same assignment/test are pretty slim. You will have to spend enough time with each student to see that he is preparing his assignment correctly and understands what and why he does this particular job in the manner it is presented in the lesson. This is another chance for you to relate some personal job experience to the subject being discussed and while answering a question make the material interesting enough that the apprentice sees the need to acquire this knowledge.

- Each assignment sheet can be outlined into the "four-step" method of instruction. The outline should assist you in presenting the assignment to the apprentice. In group instruction, it is recommended that the class period include the following:

THE FOUR-STEP OUTLINE

Step I Introducing the Lesson:

Call attention to interesting facts concerning the subject.

Step II Presenting the Lesson:

Demonstrate the use of necessary tools, materials, problems, and their solutions.
A well presented lesson will require the student to do a minimum of reading in the assigned texts.
Discuss problems encountered with the work topic and how they could be handled.

Step III Application:

Make use of the assignment sheets prepared for each lesson. The assignments serve not only to indicate to the instructor how well the assignment was presented but as a valuable aid to the learner.

Step IV Checking and Follow-Up:

Check the assignment worksheets for completness before mailing to the resident instructor. After the resident instructor has approved the assignment and sent it back to you, return the paper to the apprentice and give him individual help on any portion of the assignment which he may have had a problem with. Call attention to common errors and discuss the problems or questions that were incorrect.

- Testing Procedures:

1. There are a number of scheduled tests which the apprentice must complete as a part of his related technical training. These generally follow a related group of assignments and will be sent as the students progress toward the end of one of these study groups.

2. These tests can be of the regular "exam type" or of the "open book" type, depending on the material to be covered and the instructor's preference.

3. All tests should be checked in detail before sending to the resident instructor for approval/grading. After it has been returned to you, go over the questions missed and be sure the apprentice understands the material before he moves into something else in the assignment sheets.

- Textbooks:

Please note that the assignment references for textbooks are listed as follows:

The National Electrical Code references are "Articles."

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ASSIGNMENT REFERENCES

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		*Note # 1 *Note # 9	*Note # 4	*Note # 2	*Note # 3	*Note # 9
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*Note # 1: Page Numbers Listed
*Note # 2: Article Numbers Listed
*Note # 3: Division and Section Numbers Listed
*Note # 4: Chapter and Page Numbers Listed

*Note # 5: Trip to Contractor's Shop to See Tools
*Note # 6: Trip to Contractor's Shop to Visit Warehouse
*Note # 7: Safety and First-Aid Specialists--Visitor, Lecture and Demonstration
*Note # 8: See Orientation for Reference List
*Note # 9: Basic Math References in left column are 2nd edition; Basic Math References in last column are 3rd edition (1972).

ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	OTHER MATERIALS
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ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	OTHER MATERIALS
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YOUR FUTURE IN THE ELECTRICAL INDUSTRY

DESIRED RESULTS:

1. To attain a better understanding of the Apprenticeship Agreement.
2. To reveal the many opportunities that exist in the electrical industry.
3. To attain a thorough understanding of the objectives and operation of the related instructional program.

PRESENTING THE LESSON:

1. Explain and discuss the Apprenticeship Agreement.
2. Show the apprentice the many opportunities in the electrical industry.
3. Give them some advantages and disadvantages or hazards of the trade.
4. Explain the related instructional benefits in detail, especially in relation to electricity.
5. Briefly outline the course and how to use it.
6. Explain how the "Basic Mathematics Review" will be handled.
7. Call to the attention of the apprentices the "Tips on How to Study." They should read and reread this material.

APPLICATION:

Ask the class to read the material again on "Your Future in the Electrical Industry."

CHECKING AND FOLLOW-UP:

Discuss any questions that individuals may ask concerning the apprenticeship and the electrical industry.

YOUR APPRENTICESHIP

DESIRED RESULTS:

1. To understand the role of the local committee and the EMPLOYER in apprenticeship training.
2. To study all facets of apprenticeship training and how the program operates during the four years of service.

PRESENTING THE TOPIC:

1. Give the apprentices a general review of what is expected of them during the four years of indenture. Discuss the Standards of Apprenticeship.
2. Discuss the role of the local committee. In some places an interested committee member may be asked to meet with the class.
3. Discuss the role of the EMPLOYER and how he looks to apprentices for future foremen.
4. Sell them on the idea that apprenticeship will lead to a life's work worth the effort they put into it.
5. Discuss the importance of RELATED TRAINING to the apprentice.

APPLICATION:

Give the students time to complete the answers for the lesson.

CHECKING AND FOLLOW-UP:

Ask individual students to read the answers to questions. Then discuss each question and decide upon the best responses.

EMPLOYEE, EMPLOYER, AND CUSTOMER RELATIONS

DESIRED RESULTS:

1. To aid the apprentice in becoming a well-rounded employee.
2. To give the apprentice an insight into the general organization, plan, and function of an average contracting firm.
3. To show the importance of the local apprentice agreement.
4. To stress that the apprentice represents the company in the eyes of the customer.

INTRODUCTION:

Many employees have no knowledge of the problems which must be solved by employers. In many cases, misunderstandings will be prevented and better employer-employee relations will result when an employee understands some of the problems. Where action of an employee can assist the contractor in operating his business profitably, it enables the contractor in operating his business profitably, it enables the contractor to make money and be able to stay in business and provide work for his employees. The apprentice must sell his firm and his services to his customers.

PRESENTING THE LESSON:

The instructor should use the Information Sheets prepared for this lesson and stress all the ideas presented to the apprentice. Bring in other ideas that may be presented in the lesson that affect employee-employer relations. How should the apprentice care for the company's tools and transportation equipment? What are the types of organizations and how do they operate? How do human relations and salesmanship apply to the work of the apprentice?

APPLICATION:

The apprentices should study the Information Sheets and answer the questions listed which will be discussed in a class session.

TOOLS AND EQUIPMENT

DESIRED RESULTS:

1. To learn the names, uses, and care of the basic tools used on the job.
2. To stimulate the students' interest in the use of catalogs to learn the names of tools.

MATERIALS AND REFERENCES:

1. Tool kit of hand tools used in the trade.
2. Catalogs of electrical tools

INTRODUCTION:

The lesson materials are used primarily to introduce the basic tools of the trade for material handling, fabrication and assembly, and installation.

PRESENTING THE LESSON:

The value of this lesson lies in the discussion of tools. Be sure to discuss the proper use and care of tools. Warn the apprentice to respect the tools of others, especially those furnished by the contractor.

APPLICATION:

Using the assignment sheets, the students will fill in the common names of tools used by apprentices and journeymen.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

CONSTRUCTION MATERIALS

(Conduit and Cable Fittings)

DESIRED RESULTS:

1. To help the beginner to learn the names and uses of the more basic materials of the trade.
2. To use the electrical catalogs for specifications of materials and how to order them

MATERIALS AND REFERENCES:

1. Samples of various materials; switches, boxes, connectors, clamps, conduit, wire, lighting equipment, etc.
2. Catalogs from various supply houses.
3. Electrical Conduit and Cable Fittings, Thomas and Betts. (if available)

INTRODUCTION:

The samples of various materials and the use of catalogs will introduce a general discussion of materials as used in your area. The bulletin, Electrical Conduit and Cable Fittings, will show the picture and use of fittings for raceways and cable. All materials must be electrically safe.

PRESENTING THE LESSON:

Best results will be achieved by introducing a general discussion of materials as used in your area. The common trade name for much of this material will vary from place to place, so be sure to supply the class with the common usage name for your area. Make use of the electrical catalogs and information sheets prepared for the lesson.

APPLICATION:

Using the information sheets, the student should study the classifications, sizes, and rating of equipment along with related items. Review the NEMA enclosure types and explanations for your information.

CHECKING AND FOLLOW-UP:

Hold a discussion-type class by reviewing the Information Sheets.

SAFETY AND FIRST AID

DESIRED RESULTS:

1. To impress on the apprentice the need for him to practice SAFETY.
2. To keep the apprentice aware of the hazards of his job and to do all he can to improve SAFETY in the electrical construction work.

MATERIALS AND EQUIPMENT:

1. Safety posters and slogans
2. Safety manuals
3. First-aid manuals

INTRODUCTION:

Emphasize to the students that two of the major hazards of a construction job are falling objects and falls of workmen. The practice of good housekeeping will help to eliminate many hazards that result in accidents.

There seems to be a tendency to skip safety as a subject that is not very important. However, if you can prevent a broken bone for yourself or a fellow workman through good housekeeping practices, it would be a very important accomplishment.

Great strides have been made in safety and safety education in the construction field in recent years. There is still a great deal of room for improvement. In the electrical construction work, we must constantly keep ourselves aware of the hazards of our job. Each worker must continue to improve safety in his job daily--first of all for his own benefit, as well as for the sake of his family, his fellow workmen, and his employer.

Point out that many construction electricians have not only been crippled but also have died because of unsafe practices on ladders. Point out any local accidents caused by unsafe use of ladders. Experience has proven that the most effective way to reduce accidents is to concentrate on one phase of the accident problem at a time.

PRESENTING THE LESSON:

The instructor should give illustrations to encourage the apprentice to develop clean personal and safety habits. To instill in him a sense of responsibility and goodwill for his employer and all concerned will prove of great value.

In this and future lessons, safe practices will be discussed on many topics such as: ladders, tools, scaffolds, eye protection, and others. Careful consideration and study of such items may eliminate an accident to you or a fellow workman.

A few suggested things to do to make this lesson more effective:

1. Make it a general discussion of SAFETY.
2. Have a good many SAFETY posters available to illustrate a particular point.
3. Have men suggest SAFETY slogans - record and discuss some.
4. Have men discuss SAFETY practices they have observed on the job.
5. Have men discuss unsafe conditions they have observed on the job.
6. Have the class discuss accidents or near accidents they have witnessed where ladders were involved. Using the ladders for demonstrations:
   a. Point out "unsafe conditions" in using ladders.
   b. Point out "unsafe acts" while using a ladder.

APPLICATION:

Have the students answer the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers to the questions.

INTRODUCTION TO ELECTRICITY

DESIRED RESULTS:

To introduce basic electricity by explaining the behavior of electrons.

INTRODUCTION:

Some of the mystery which has veiled the subject of electricity in the past has been removed. For many years, the natural laws and observed behavior of electricity were the only available sources of information for a study of this subject. The electron theory of matter, which has been certified by these natural laws, has led to a better understanding of the nature of electricity. The knowledge gained from this lesson will be the foundation upon which many later lessons will be developed.

PRESENTING THE LESSON:

It should be stressed that no one has ever seen an atom or an electron. There has been a large amount of research time devoted to the subject, and most of the evidence accumulated from this research supports the electron theory. The behavior of electrons and most atoms generally follows a definite pattern. For this reason, it is possible to predict mathematically the results of many experiments before they are performed. These predictable results have been sufficiently stable to make it feasible to label the study of electrons a science.

There are still many unpredictable results of experiments and research problems. After the discovery of the electron in 1897, scientists finally became convinced that all matter was composed of a positive mass having a definite number of electrons in orbit around this mass. The number of electrons determined the type of matter. This idea provided a very neat package. There was only one thing wrong with the theory--it was not exactly true.

There is now supporting evidence to indicate that some atomic structures are composed of more than twenty components in addition to the originally known parts. Scientists believe there are still others not yet discovered.

Some restraint should be used in defining the electron and electricity. It appears that there is a close association between these two factors, but keep in mind that there still is not an accepted definition for electricity.

In using the sun and the orbiting planets as an analogy for the description of an atom, be very careful not to leave any erroneous impression. The planets orbit about the sun very nearly in the same place. The electrons may or may not follow this pattern. Some electrons are transients. Even though it may be possible, so far as we know there is no transient planet in our solar system.

APPLICATION:

Students should complete work on the assignment sheets for this lesson. Allow time for them to discuss questions about electrical theory.

CHECKING AND FOLLOW-UP:

Check the worksheets and allow time for the class to find correct answers. Discuss the questions that need explanation.

OHM'S LAW

(Simple Circuits)

DESIRED RESULTS:

1. To understand the relationships of voltage, current, and resistance in an electric circuit.
2. To show how the formula may be used to determine the voltage, current, and the resistance of a circuit.

INTRODUCTION:

George S. Ohm, a German physicist, discovered that the amount of current that passes through a conductor depends upon the amount of pressure (voltage) and the resistance (ohms). Ohm's Law is expressed by three forms of equations:

$$E = I \times R \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$$

Emphasize the fact that students who have trouble studying electrical subjects have failed to learn and apply Ohm's Law.

PRESENTING THE LESSON:

The relationship of amperes, ohms, and volts can be expressed by the formula

$$I = \frac{E}{R}$$

(1) "I" stands for the intensity of the current flow in amperes.
(2) "E" stands for the electromotive force in volts.
(3) "R" stands for the resistance in ohms.

Show how Ohm's Law is so helpful in using what one learns about electricity, that the student should know how to use the formula in all its forms.

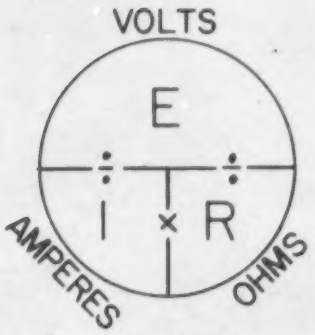
Adapt the formula to practical problems involving a house wiring circuit.

APPLICATION:

Have the students complete the assignment sheet.

CHECKING AND FOLLOW-UP:

Check assignment sheets.



OHM'S LAW

OHM'S LAW
(MODIFIED)

CURRENT

DESIRED RESULTS:

1. To inform the student of the nature of OHM'S Law and to show how this formula is used to determine the current of a circuit.
2. To understand that when electrons are put into motion, we have current flow.

INTRODUCTION:

The next three lessons will involve the three components of a circuit that make up Ohm's Law--namely, current, voltage, and resistance. Each component is studied individually and each lesson will point out the main points for the apprentice to learn and understand.

PRESENTING THE LESSON:

We have learned that all matter is composed of various particles, one of which is an electron. Now in this lesson when we put electrons in motion, there is current flow.

The main point of this lesson is to understand that current flow is the movement of electrons along the conductor. Current flow in a circuit changes as a result of resistance and voltage changes. The length, cross section, and different materials of a conductor will cause the current in a circuit to vary. Experiments show that when the voltage is decreased, the current flow is increased. The unit of measurement, symbol, and nomenclature used in conjunction with current are also pointed out.

APPLICATION:

Have the students answer the questions on the assignment sheet. Give assistance where needed.

CHECKING AND FOLLOW-UP:

Check the papers.

RESISTANCE

DESIRED RESULTS:

1. To understand that RESISTANCE opposes the flow of current in an electrical circuit.
2. To study the resistivity of the common conductors.
3. To learn the unit of measurement, symbol, and names used in conjunction with the term RESISTANCE.

INTRODUCTION:

Review the main points discussed about current and voltage. This lesson has one main point - resistance is an opposition offered to the flow of current in an electrical circuit.

PRESENTING THE LESSON:

Show by the use of Ohm's Law formula the relationship of RESISTANCE to current and voltage. The unit of measurement for resistance is the OHM, and the symbol for resistance is R. Adapt the formula ($I = \frac{E}{R}$) to find resistance. EXPLAIN how to change the formula to have $R = \frac{E}{I}$.

Use this formula to find the resistance in an electric circuit by substituting known values. Remember--to find the resistance in OHMS, one divides the E.M.F. in volts by the current in amperes.

APPLICATION:

Have the students complete the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

ELECTROMOTIVE FORCE

(Voltage)

DESIRED RESULTS:

1. To understand that voltage is the force or pressure that causes the electron to move.
2. To learn the unit of measurement, symbol, and names used in conjunction with voltage.

INTRODUCTION:

Review the difference between current and voltage and show their very close relation. Voltage is the second of the three important terms associated with Ohm's Law.

PRESENTING THE LESSON:

Voltage or electromotive force of an electric circuit is the pressure which causes the current to flow. It is measured in volts and is represented in the formula by the letter "E." Show from the references the individuality of the voltage, but at the same time its close relationship with the current.

The class should use time for additional study in the reference material.

APPLICATION:

Have the students to answer the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the papers.

POWER AND WORK

DESIRED RESULTS:

1. To acquaint the student with some of the terms of electrical energy that apply to work and power.
2. To inform the learner that work is done when force accomplishes something (weight x distance). Power is the work done times the speed of doing it.
3. To solve problems involving the power formula.

INTRODUCTION:

This lesson will introduce the students to the use of terms such as horsepower, watts, etc. Ask the students to check the labels on electrical equipment they see on the job for horsepower, watts, KW, voltage, and current rating. An electrician may be called upon to install a unit of equipment rated in horsepower, or watts, or voltage only. The electrician must decide how much current the piece of equipment will demand. Knowing the current needed, he must install the proper size wire and protect the circuit and equipment with the proper fuse. The power equations studied in this lesson will be used many times to find information not given on the name plate of electrical equipment.

PRESENTING THE LESSON:

A thorough understanding and the ability to use the power equations should be stressed. Point out to the students the close relationship between the following power equation and the Ohm's Law equation.

$$P = IE \qquad E = \frac{P}{I} \qquad I = \frac{P}{E}$$

APPLICATION:

Have the students answer the questions and work the problems on the assignment sheet. Give assistance if needed, but do not give the answer.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

SERIES CIRCUITS

DESIRED RESULTS:

To teach the student the relationship of voltage, current, and resistance in a series circuit.

INTRODUCTION:

Be sure that the students understand that:

1. The current is the same in any part of the circuit.
2. The total resistance is the sum of resistance in the various parts.
3. The total circuit voltage is the sum of the voltages in the various parts.

PRESENTING THE LESSON:

1. Explain how cells may be connected to provide a higher voltage than is produced by one cell.
   a. Dry cells supply current at a pressure of 1.5 volts no matter what their size or shape.
   b. Certain devices require higher voltages for their operation and will work at their maximum when operated at their rated voltage.
   c. Connect the cells in series.
      (1) The voltage resulting will be the sum of the voltage of individual cells. (Flashlights, "B" batteries, and auto storage batteries are examples of series connections.)
2. The current in a series circuit is the same in all parts of the circuit. If the ammeter is placed at any point in the circuit, it will read the same.
3. The total resistance of a series circuit is equal to the sum of the various resistances in the circuit. Expressed as R (totals) = $R_1 + R_2 + R_3$, etc.
   a. Point out that adding resistance to a series circuit reduces the current flow.
   b. That the current flow would read the same on an ammeter placed at any point in the series circuit.
   c. To find the current flow in a series circuit, it is necessary to know two things:
      (1) The circuit voltage
      (2) The total circuit resistance

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APPLICATION:

Have the students work on problems and questions.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

PARALLEL CIRCUITS

DESIRED RESULTS:

1. To acquaint the student with the relationship of current, voltage, and resistance in a parallel circuit.
2. To understand that the total resistance of a parallel circuit is less than the smallest resistor.

INTRODUCTION:

The parallel circuit is another method of connecting electrical devices in a circuit. There are several ways of calculating the total resistance of a parallel circuit. To help the students to visualize the problems, it is well to require them to draw a circuit diagram for each problem. Many problems in this assignment are not long or complicated but will give the student good practice in OHM'S Law calculations.

PRESENTING THE LESSON:

Show several ways of calculating the total resistance of a parallel circuit. Explain that the understanding of more than one method of solving the problems will help them later with control and electronic work.

Show that two or more resistors of the same size or various sizes may be connected in parallel; the total resistance of a parallel circuit is ALWAYS less than the value of the smallest resistor.

Explain that in studying the theory of electricity, we often use a resistor in the circuit to represent the load. It is easier to draw the symbol for a resistor than a picture of an appliance.

SUMMARY OF RULES FOR PARALLEL CIRCUITS:

1. The total current is the sum of the currents in various parts.
2. The voltage of a parallel circuit is the same in any part of the circuit.
3. The resistance is the reciprocal of the sum of the reciprocals of the various parts.

APPLICATION:

Have the students work the problems on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

COMBINATION CIRCUITS

(Series and Parallel Circuit Connections)

DESIRED RESULTS:

1. To acquaint the learner with the elementary problems of series and parallel circuits.
2. That the student learn to think in terms of and visualize the combination of series and parallel hookups.

INTRODUCTION:

Stress the understanding of the relationship of resistance, voltage, and current as in other OHM'S Law lessons.

The student should be well acquainted with the various methods of interconnecting circuits when greater amounts of voltage and current are needed. Most workmen deal with circuits in terms of parallel connections and become confused when they get into a combination of series and parallel hookups. Electrical energy, if wrongfully directed in a circuit, will oppose the direction of the desired current flow with harmful results.

PRESENTING THE LESSON:

You may draw similar circuits and ask the student to tell how the current and voltage would be distributed. Then calculate the voltage, current, or resistance of the circuit. This type of illustration will make a lasting impression on the student.

Remember to always work the SERIES and PARALLEL groups separately within the combined circuit and then solve for the whole combination.

APPLICATION:

Have the student answer questions and work the problems on the assignment sheet. Give individual suggestions where needed, but do not answer the question for the student.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

WIRE CONSTRUCTION

(Paths for the Electric Current)

DESIRED RESULTS:

1. To acquaint the learner with the fact that all electrical devices receive their energy from a source by means of metallic conductors.
2. These conductors are separated or supported by nonmetallic materials called insulators.

INTRODUCING THE LESSON:

Call attention to the fact that wires are very much like pipes in that they permit the flow of electricity, but whereas pipes are hollow, wires are a solid. It is important to know the characteristics of these "electrical pipes," called conductors, and how they are made safe within the home and in appliances.

PRESENTING THE LESSON:

1. Electrical devices are connected to a source by wires to provide a path for the electric circuit.
   a. Make a sketch:
      (1) Two wires are needed to complete a circuit.
      (2) Electric current must flow from the source to the device and return to the source.
2. Electrical devices are made of different materials.
   a. Show:
      (1) Difference of materials in an insulated wire.
      (2) Different materials in a plug.
      (3) Define materials such as metallic and nonmetallic
3. Demonstrate: "conductors and insulation"
   a. Samples of wire and insulating materials are studied.
   b. Experiment showing materials that conduct current and insulate current.

APPLICATION:

Have learner work and hand in the assignment sheet. Give individual help where needed.

CHECKING AND FOLLOW-UP:

Check assignment sheets.

WIRE INSULATION

DESIRED RESULTS:

1. To acquaint the student with a number of different types of wire, according to the insulation.
2. To teach the student to identify types of wire and sizes in general use on the job.

INTRODUCTION:

1. The lesson should acquaint the student with the fact that there are different types of wire classed according to the insulation. Discuss the characteristics of an ideal insulating material.
2. Call attention to the fact that the size of wire is usually expressed according to some wire gage. However, it has become standard practice in the United States to employ the American Wire Gage, also known as the Brown and Sharpe, for designating copper and aluminum wire and cable used in the electrical industry.
3. Present the six major classes of wire and cables.

PRESENTING THE LESSON:

1. Show the student samples of as many types of wire according to the insulation as possible. Have the student examine the types of wire so he can classify wire according to insulation. Discuss the different types of insulation with the class.
2. Demonstrate how to use the gage in measuring the size of wires. Wire gages are used for the measurement of diameters of wire and thicknesses of sheet metal. Wire sizes are referred to by gage numbers. The smaller the number, the larger the wire. Micrometers are gages for that purpose. Where micrometers are used, the wire diameters are expressed in thousandths of an inch.
3. The students are expected to know sizes up to No. 4 on the job.

   NOTE: A circular, mil (C.M.) is the area of a circle 1/1000 in. in diameter and is the unit for all wire measurement.

APPLICATION:

Have the students complete the answers to questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

VOLTAGE DROP

DESIRED RESULTS:

1. To understand what is meant by voltage drop.
2. To be able to use the formula to determine excessive voltage drops.

INTRODUCTION:

The two factors that must be considered in determining the size of wire to be used in an electrical circuit are the current-carrying capacity of the wire and the permissible voltage drop.

The electrician always determines current-carrying capacity by consulting tables in the various electrical codes. On the other hand, voltage drop is nearly always calculated by the electrician himself. The National Electrical Code recommends that voltage drop from service head to distribution center be not more than one percent for lighting and three percent for power loads. Voltage drop must be allowed when circuits are installed on commercial and industrial buildings, but is seldom considered for circuits on residential buildings.

PRESENTING THE LESSON:

In this lesson, the student will not learn all there is to be known about voltage drop. Teach them some of the basic facts so they can learn to figure voltage drop and how voltage drop is used in calculating the sizes of wires required for certain circuits.

Introduce the following formula and explain its use.

$$VD = \frac{K \times I \times 2L}{CM}$$

VD - Voltage drop
K = Resistance (1 mil foot of wire)
I = Amperes
L = Distance of wire one way
CM = Circular mils

Note 1: If the student has trouble rearranging the formula, it is much easier for some to substitute in the original form and solve for the unknown.

Note 2: By use of the formula, we find voltage drop, but the National Code recommendations give PERCENTAGE voltage drop.

APPLICATION:

The students will answer questions and work problems on Assignment Sheet A-18.

CHECKING AND FOLLOW-UP:

Correct the assignment sheet.

INTRODUCTION TO NATIONAL ELECTRICAL CODE

DESIRED RESULTS:

1. To acquaint the apprentice with the purpose and scope of the CODE.
2. To introduce the apprentice to the definitions and fundamental rules covered by the CODE.

INTRODUCTION:

This is the apprentice's first contact with the NATIONAL ELECTRICAL CODE. He will be working by these rules for his entire life in the electrical industry. The importance of learning the purposes and organization of the CODE cannot be over emphasized.

This lesson should give the student a clear picture of how the CODE is organized so that the apprentice may find information more easily in later assignments and on the job. The CODE is not a set of laws; it is a set of rules. It is intended for use by governmental bodies exercising legal jurisdiction over electrical installations and for use by insurance inspectors.

Article 100 contains definitions of electrical terms.

PRESENTING THE LESSON:

In the National Electrical Code Book - Article 90, which is the introduction, outlines the purpose and explains the scope of the CODE.

The best results will be obtained from all CODE lessons if they are used as study guides for the student. The instructor should lead a class discussion of the material contained in each section of the CODE used in the assignment.

Remind the students that the chief electrical inspectors usually exercise legal jurisdiction over electrical installations through city ordinances or laws based on National Electrical Code. Some communities use the CODE as it is for their local electrical ordinance. Most citizens realize that the CODE is only the minimum standard so they improve on certain portions for their use. If the electrician knows the National Electrical Code, he may be able to work in any locality, but he should become familiar with local ordinances.

APPLICATION:

Have the students answer the questions using the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

GENERAL REQUIREMENTS FOR WIRING INSTALLATIONS

DESIRED RESULTS:

To acquaint the apprentice with the general requirements for wiring methods and installations.

INTRODUCTION:

This assignment contains information about overcurrent protective devices and fuses, sizes of conductors, types of conduit, installing boxes, grounds and grounding, and various raceways. This information will be very useful to the apprentice in his daily work on the job.

The student may not realize the fact, but it requires a skilled craftsman to make a concealed electrical installation in an old building. It is essential that he leave the building in good repair when he is finished.

PRESENTING THE LESSON:

There are twenty-two types of wiring for general use for power and light systems.

1. Call attention to the method of determining the minimum and maximum size of conduit for interior installations. The current capacity of a conductor is limited by the temperature its insulation will withstand.
2. The National Electrical Code requires that fuses or circuit breakers be provided for all ungrounded conductors to open the circuit when the current is abnormally high.
3. Conduit systems contain both junction and outlet boxes. A junction box is placed where several conduit runs intersect. It provides means for pulling in the wire and serves as an enclosure for the connections that must be made. It is possible to ground the entire system with one ground connection. Outlet boxes may be used to enclose a switch which controls the current in a circuit or fitted with outlets and special cover through which light and power loads can be connected.
4. Grounding is executed by connecting one wire from a wiring system or the metallic covering of electrical devices to a steel beam of a building, to a ground strap fastened to a water pipe, or a pipe driven in the ground. Grounding is necessary to protect life and property.

APPLICATION:

Have the students find the answers to the questions on the assignment sheets.

CHECKING AND FOLLOW-UP:

Check the answers.

SINGLE CONDUCTOR WIRING

DESIRED RESULTS:

1. To learn the definition and use of open wiring on insulators, and concealed knob-and-tube work.
2. To acquaint the apprentice with the construction and restrictions in the use of single conductor wiring.

PRESENTING THE LESSON:

Open wiring on insulators may be used for exposed work, either inside or outside buildings and in dry or wet locations. Open wiring on insulators shall not be used in (1) commercial garages, (2) theaters, (3) motion picture studios, (4) hoistways, and (5) hazardous locations.

Concealed knob-and-tube work may be used in hollow spaces of walls and ceilings. It has the same restrictions as open wiring.

APPLICATION:

Have the students complete the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers.

CABLE ASSEMBLIES

DESIRED RESULTS:

To acquaint the apprentice with the construction and restrictions in the use of the various cable assemblies.

PRESENTING THE LESSON:

1. A nonmetallic sheathed cable is an assembly of two or more insulated conductors having an outer sheath of moisture-resistance, flame-retardant, nonmetallic material.
2. A service-entrance cable is a conductor assembly provided with a suitable overall covering, primarily used for services of the following types:
   a. Type SE, having a flame-retardant, moisture-resistant covering.
   b. Type USE, having a moistrue-resistant covering and recognized for underground use.
3. An underground feeder and branch circuit shall be an approved type UF cable in sizes No. 14 to No. 4/0 AWG, inclusive. When this cable is used for grounding purposes only, it may be an approved size of uninsulated or bare conductor.

APPLICATION:

Have the students complete the answers to the questions on the work-sheet. Use the Code book when it is needed.

CHECKING AND FOLLOW-UP:

Check the answers.

METALLIC SHEATHED CABLES

DESIRED RESULTS:

To acquaint the apprentice with the definition and use of the various metallic sheathed cables.

PRESENTING THE LESSON:

1. Mineral insulated - metal sheathed cable - Type MI
   This is a cable in which one or more electrical conductors are insulated with a highly compressed refractory mineral insulation and enclosed in a liquidtight and gastight metallic tube sheathing. It may be used for services, feeders, and branch circuits in both exposed and concealed work and in dry and wet locations.
2. Aluminum sheathed cable - Type ALS
   This cable is factory assembled, consisting of one or more insulated conductors enclosed in an impervious, continuous, closely fitting tube of aluminum. It may be used with approved fittings for terminating and connecting to boxes, outlets, and other equipment. This cable may be used in both exposed and concealed work and in dry and wet locations.
3. Metal-clad cable - Type MC and AC series
   This is a fabricated assembly of insulated conductors in a flexible metallic enclosure. The uses are explained in the Code book.

APPLICATION:

Have the apprentices to study the assigned Code articles for the uses of these cables. Give special attention to type MC and AC cables. Then they will answer the questions on the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers on the worksheets.

SPECIAL CORDS AND WIRES

DESIRED RESULTS:

To acquaint the apprentice with the trade names, construction, and restrictions in the uses of flexible cords and fixture wires.

PRESENTING THE LESSON:

1. Discuss flexible cords, the trade names, size, conductors, insulation, and outer covering. (Use the Code book.)
2. Discuss fixture wire, the trade names, type letter for designation, insulation and thickness, type of outer covering. (Use the Code book.)

APPLICATION:

Using the assignment or worksheets, have the student complete the questions. (Use Code book.)

CHECKING AND FOLLOW-UP:

Check the answers on the worksheets.

RIGID METAL CONDUIT

DESIRED RESULTS:

To acquaint the apprentice with some of the techniques connected with conduit installations that must be learned through experience.

INTRODUCTION:

Single family dwellings are seldom wired with rigid metal conduit because of the high cost of such an installation. However, it is widely used in industrial plants. Electrical metallic tubing is sometimes employed because the cost for installation is much less than for rigid conduit. The cost is still somewhat higher than that for a knob-and-tube or a cable-type installation.

It is common practice to install a rigid conduit or an electrical metallic tubing service raceway even though the bulk of the installation is carried out by some other method of wiring.

Hydraulic Conduit Benders

Industrial installations of rigid metal conduit have routinely presented electricians with jobs of great proportions; however, with the hydraulic equipment in use today, this work is easily accomplished. Various attributes of fluid or hydraulic power equipment recommend it to the electrical industry. Hydraulic tools readily increase 100 pounds of applied effort to 200,000 pounds of output. The tools are versatile, light in weight, compact in size, and completely mobile so that one man can carry a hydraulic set capable of moving 50 tons.

In recent years, electrical installations have become larger and more complicated with the result that the electrician is called on to make many large bends in conduit. Hydraulic equipment is used to bend conduit having a diameter larger than 1". Conduit of smaller dimensions is usually bent by a hand bender. The two principal types of benders for large conduit are: (1) a "one-shot" bender which makes a full 90° bend with a single stroke and setting; and (2) a segment bender which requires several smaller, single-stroke stages to complete a 90° bend.

PRESENTING THE LESSON:

Try to have a small hydraulic conduit bender to demonstrate to the class. The student should know how the machine operates as well as its use.

Using the information sheet on rigid metal conduit bending as a guide, the following topics should be discussed:

1. Radius of bend
2. Principles of precision bending
3. Concentric bending
4. General purpose bending
5. Bending the angle

To review important topics on rigid metal conduit wiring referred to in American Electricians' Handbook.

APPLICATION:

Have the students complete the answers to the questions on the assignment sheets.

CHECKING AND FOLLOW-UP:

Check the answers.

ELECTRICAL METALLIC TUBING

DESIRED RESULTS:

To acquaint the apprentice with the construction and restrictions in the uses of electrical metallic tubing.

INTRODUCTION:

Electrical metallic tubing (EMT) sometimes called "thin-wall conduit" has a wall thickness less than that of rigid conduit, and it bends more easily. It is connected with compression or indentation-type fittings, since it is too thin to thread. A special tool is used to install indentation fittings.

PRESENTING THE LESSON:

Electrical metallic tubing is installed and has the same use for both exposed and concealed work as rigid conduit except it cannot be used where subject to severe physical damage. When used in wet locations or in concrete, fittings of the type to prevent water entering the conduit shall be used.

Tubing and fittings may be obtained, made of an alloy having corrosion-resisting characteristics. This makes them especially suitable for use in many locations where there are corrosive fumes, or excessive moisture.

No tubing shall be used smaller than 1/2 inch in diameter, electrical trade size, except for under plaster extensions. The maximum size tubing shall be the 4-inch electrical trade size.

Bends in the tubing shall be made that the tubing will not be injured and that the internal diameter of the tubing will not be effectively reduced. One run of conduit should preferably include not more than three "quarter" bends.

APPLICATION:

Have the students complete the answers to the questions on the assignment sheets for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

RIGID NONMETALLIC CONDUIT AND FLEXIBLE METAL CONDUIT

DESIRED RESULTS:

To acquaint the apprentice with the construction and restrictions in the uses of flexible metal conduit and rigid nonmetallic conduit.

INTRODUCTION:

Flexible metal conduit is used in difficult places requiring a number of irregular bends or where flexibility is required, such as connecting a motor to rigid conduit, not exceeding 24 inches in length.

Flexible metal conduit is used and installed according to the rules and practices for installation and use of armored cable. It is installed and conductors are pulled into it in the same way conductors are installed in rigid conduit. The size of flexible conduit is determined by the inside diameter.

Flexible nonmetallic conduit is used for both low voltage and high voltage wiring within the limitations of the N. E. Code. Because of its resistance to corrosion and high moisture and vapor areas, it is becoming a widely used raceway material.

PRESENTING THE LESSON:

Installations of flexible metal conduit shall comply with the provisions of the Code listed in paragraph 350 of the Code.

Flexible metal conduit shall not be used in:

1. Wet locations, unless lead-covered type
2. Hoistways, except as provided in Section 620-21
3. Storage-battery rooms
4. Any hazardous location except permitted in Sections 501-4 and 502-4
5. Where rubber-covered conductors are exposed to oil, gasoline, etc.

MINIMUM SIZE - No flexible metal conduit less than one-half inch electrical trade size shall be used except as permitted in Section 3503.

Straps or other means of securing the conduit in place should be spaced much closer together for flexible conduit than is necessary for rigid conduit. Every bend should be rigidly secured so that it will not be deformed when the wires are being pulled in, thus causing the wires to bind.

LIQUIDTIGHT FLEXIBLE METAL CONDUIT - This conduit is similar in construction to the flexible metal conduit but is covered with an outer sheath of material to make a liquidtight jacket.

Connectors and grounding bushings are available for terminating the conduit and providing effective grounding connections. It is used in the wiring of machine tools, motors, or portable equipment where flexibility of connection is required.

Paragraph 351-2b lists the conditions under which liquidtight flexible metal conduit shall not be used.

1. Where it is subject to mechanical injury
2. Where it is in contact with rapidly moving parts
3. Where the temperature is above 60°C or 140°F
4. In any hazardous location.

The maximum sizes of the conduit and conductors to be installed are listed in Article 351, paragraphs 351-3 and 351-4.

Installations of rigid nonmetallic conduit shall comply with the provisions of the Code listed in Article 347.

Because of the many types of nonmetallic conduit available, the instructor should spend some time in acquainting the student with these types:

(1) Fiber
(2) Asbestos
(3) Cement
(4) Soapstone
(5) Rigid polyvinyl chloride
(6) High density polyethylene

Since each material has its own unique methods of installation and assembly, the instructor may wish to have an outside materials supplier have a demonstration of the various materials.

APPLICATION:

Have the students complete the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers to the questions.

OUTLETS, SWITCH AND JUNCTION BOXES, AND FITTINGS

DESIRED RESULTS:

1. To acquaint the apprentice with outlet and junction boxes and fittings used in electrical wiring.
2. To study carefully the uses of various types of outlet and switch boxes, and their accessories.

PRESENTING THE LESSON:

Discuss the various boxes, giving the correct names, shapes, uses, and how to attach the wiring. Show how the boxes for interior wiring are classified. Describe the use of nonmetallic boxes and the straight-through junction boxes. Discuss outlet switches and their use.

APPLICATION:

The student should complete the worksheet assignment for this lesson.

CHECK AND FOLLOW-UP:

Check the assignment sheets.

AUXILIARY GUTTERS AND WIREWAYS

DESIRED RESULTS:

1. To learn the purposes and correct use of auxiliary gutters and wireways.
2. To learn the restrictions as to the size and number of conductors allowed in the various auxiliary gutters and wireways.

PRESENTING THE LESSON:

Using the National Electrical Code (latest edition) and other references, discuss the use and installation of auxiliary gutters and wireways. Call attention to the various restrictions and rules to follow in making the installations.

APPLICATION:

The students should answer all questions on the worksheets for this lesson.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

CABINETS AND CUTOUT BOXES

DESIRED RESULTS:

1. To learn the purposes and the installation regulations for cabinets and cutout boxes.

2. To review the construction specifications for cabinets and boxes.

PRESENTING THE LESSON:

Discuss the purposes and installation regulations for cabinets and boxes. Using the N. E. Code, review the construction specifications of cabinets and boxes. Discuss how the conductors entering cabinets and cutout boxes are protected.

Review the specifications for spacing within cabinets and cutout boxes. Explain the use of conduit bushings and locknuts on cabinets and cutout boxes.

APPLICATION:

The student should answer the questions on the worksheet.

CHECKING AND FOLLOW-UP:

Check the questions on the worksheet.

STORAGE BATTERIES

DESIRED RESULTS:

1. To acquaint the student with the construction and operation of storage cells.

2. To acquaint the student with the chemical properties of different types of cells.

3. To teach the student to understand electrolysis, and other instances of electrochemical action.

INTRODUCING THE LESSON:

The study of batteries could be a course in itself, but in this lesson the student should become acquainted with the chemical properties of several types of cells. One of the major problems involved in electrical systems, depending on storage cells for part-time operation, is the proper battery care and maintenance. The facts explained in this lesson should be thoroughly understood.

PRESENTING THE LESSON:

Point out:

1. That cells, such as dry cells, that cannot be charged are called "primary cells" to distinguish them from those that can be recharged, known as "secondary cells" or the storage battery.

2. A storage cell does not store electrical energy; it stores chemical energy and then changes the chemical energy into electrical energy as needed.

3. When the chemical energy has all been changed to electrical energy, it can be restored only by sending a current through the cell.

4. There are two main types of storage cells in use. The "lead acid" used on all motor-driven vehicles and the "Edison cell" which is extremely rugged but has low cell voltage. The Edison cells are not as efficient as lead acid cells, as they return only 60 to 65 percent of the charging energy.

APPLICATION:

Have the students work and hand in assignment sheet.

CHECKING AND FOLLOW-UP:

Check assignment sheets.

FUSES AND OVERCURRENT PROTECTIVE DEVICES

DESIRED RESULTS:

1. To learn that in electrical work every circuit must be provided with overcurrent protection.

2. To understand the National Electrical Code standard fuse ratings and the sizes required for protection of certain devices.

INTRODUCTION:

In electrical work every circuit must be provided with overcurrent protection. It may be a 13,200 volt transmission line carrying 200 amperes, or it may be 110 volt lighting circuit with a load of 10 amperes. Each must have some form of protective device for the possible overload of current for the protection of both circuits and apparatus.

In this lesson we are primarily concerned with the simpler circuits requiring the common types of overcurrent protective devices, such as, the plug fuses and the cartridge fuses. As we advance in the program, the more complicated protective devices will be investigated.

PRESENTING THE LESSON:

The need for the use of protective devices as fuses has been discussed. You have learned that excessive current may seriously damage electrical equipment - motors, instruments, etc. Fuses are cheap--other equipment much more expensive. When the fuse which is connected in series with the equipment is blown, the circuit will open before the excessive current damages the equipment.

It is important that you always use fuses with the proper current rating. The rating should be slightly higher than the greatest current you expect in the circuit. Example: Since the range of an ammeter is 0 to 1 ampere, a 1.5 amp fuse should be used to protect the equipment. In protecting equipment to use fuses with too low current rating will result in unnecessary blowouts, while one with too high current rating may allow dangerously high currents to pass.

Precautions: Fuses are used for protection. Do not jumper out a fuse. Do not increase the size of a fuse unless and until you are sure it is the right thing to do.

APPLICATION:

Answer the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

LIGHTING FUNDAMENTALS

DESIRED RESULTS:

1. To help the student understand what light is and how it is produced.
2. To help prepare the student to utilize the experience he receives on the job in relation to lighting.

INTRODUCTION:

The electrician should have a basic understanding of the nature and character of light. You may not be asked to design a large lighting system but you will spend much of your working time installing equipment. It will help you to know the basic things about light--what light is and how it is produced. Intensive study of applied light and its influence upon man has developed only recently. We have witnessed the development of several new light sources and the demand for safe equipment and higher illumination levels for industrial and commercial buildings.

There are four separate divisions in the development of a lighting system that must be considered.

1. Design of the lighting equipment.
2. Manufacture of the lighting fixture.
3. Design of the lighting layout and system.
4. Actual installation of the equipment.

PRESENTING THE LESSON:

1. Discuss and define the following terms:
   a. Light
   b. Foot-candle
   c. Watt
   d. Lumen
   e. Reflected light
   f. Refraction
2. List the three primary colors.
3. Discuss three different classes of glare.
4. Describe incandescent, fluorescent, and high intensity discharge lamps.

APPLICATION:

Have the students answer the questions on the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers.

FLUORESCENT LIGHTING

DESIRED RESULTS:

1. To acquaint the student with some of the properties and characteristics of the various types and sizes of fluorescent lamps.

2. To learn the importance of using correct equipment for replacement.

INTRODUCTION:

This lesson is concerned with the lamp, the ballast, and hints for troubleshooting fluorescent lighting systems. There are several different types of lamps; therefore, the apprentice should know which type he is working with and how it operates. Thus, he should become acquainted with some of the properties and characteristics of the various types of fluorescent lamps.

PRESENTING THE LESSON:

1. Discuss the various types of lamps.
2. Discussion questions.
   a. Why are fluorescent fixtures gaining in popularity over incandescent fixtures?
   b. For what types of installation would you recommend the use of fluorescent fixtures?
   c. In your opinion, which is the better type of lighting - fluorescent or incandescent?
   d. What is the function of a capacitor?

APPLICATION:

Have the students answer the questions on Worksheet A-34.

CHECKING AND FOLLOW-UP:

Check the answers on the assignment sheet.

HIGH-INTENSITY-DISCHARGE LIGHTING

DESIRED RESULTS:

1. To help the student understand high-intensity-discharge lighting.
2. To gain a knowledge of how the four types of ballasts shown in the worksheets operate.

PRESENTING THE LESSON:

Discuss the four types of ballasts from the material and drawing found on the worksheets for this lesson. What is the basic difference in the three major types of high-intensity-discharge lamps? Give some of the advantages and disadvantages of the five basic types of high-intensity-discharge lamps.

APPLICATION:

Have the students answer the questions on Worksheet A-35.

CHECKING AND FOLLOW-UP:

Check the answers.

BLUEPRINT READING

DESIRED RESULTS:

1. To learn how to read electrical prints.
2. To learn that specifications are the "who, what, and when" of a contract.
3. To determine the building trades involved in a contract.
4. To learn the electrical symbols and other symbols involved in a print.
5. To review how to read the various scales.

PRESENTING THE LESSON:

Prepare a number of questions pertaining to the blueprint or blueprints you use for the lesson. Many questions will involve mathematics, electrical knowledge, and electrical installation work. Use the electrical symbols sheet to learn the various symbols found on the print. Discuss a pictorial drawing and its use. Make a bill of material for a small installation.

APPLICATION:

Practice work on blueprints until the students have a good understanding of the work.

CHECKING AND FOLLOW-UP:

Check and discuss answers the students listed on the answer sheets.

ASSIGNMENT REFERENCES

NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	OTHER MATERIALS
		*Note # 1	*Note # 4	*Note # 2	*Note # 3	*Note # 5
Electrical Systems	B-1			200, 210	3-19 thru 3-29	
A. C. Instruments and Their Use	B-2		1-62 thru 1-97, 1-108, 1-118 thru 1-119, 3-22, 5-75		1-60 thru 1-218	Basic Math Pg. 356-368
Principles and Types of Transformers	B-3		3-18, 3-54 thru 56, 4-71 thru 76, 4-77 thru 79	230, 250, 450, 517	5-1 thru 36	
Single Phase Transformers	B-4		3-18, 3-54 thru 56, 4-71 thru 76, 4-77 thru 79	230, 250, 450, 517		
Three Phase Transformers	B-5		3-18, 3-54 thru 56, 4-71 thru 76, 4-77 thru 79	230, 250, 450, 517	5-81 thru 172	
Fixed Electric Space Heating	B-6			250 424, 210	9-394 thru 405	
Outdoor De-Icing and Snow Melting Equipment	B-7			426, 250,210	9-405 thru 410	

*Note # 1: Page Numbers Listed
*Note # 2: Article Numbers Listed
*Note #3: Division and Section Numbers Listed
*Note #4: Chapter and Page Numbers Listed
*Note #5: Basic Math References in last column are 3rd Edition, 1972

NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	N. E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	OTHER MATERIALS
General Installation Requirements	B-8			110		
Grounded Conductors	B-9			200, 250	9-296, 9-311	
Grounding	B-10			250	8-157 thru 170	
Branch Circuits	B-11			210	3-30 thru 55	
Appliances	B-12			100, 210, 220, 422, 430, 440	9-472 thru 477	
Feeders and Branch Circuit Calculations	B-13			210 215, 220	3-30 thru 3-55	
Services	B-14			230, 250	9-346 thru 356	
Temporary Wiring	B-15			305		
Outside Branch Circuits& Feeders	B-16			730, 225	8-86 thru 87	
D. C. Motors and Generators	B-17		3-8 thru 3-12 5-1 thru 5-20	430 445	7-1 thru 7-117 7-132 thru 7-142 7-206 thru 7-213	
Single Phase Motors	B-18		5-97 thru 5-112	430	7-187 thru 201	Basic Math Pg. 398
Three Phase Motors	B-19		5-97 thru 5-112	430	7-144 thru 186	

NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	OTHER MATERIAL
Motor Circuits	B-20			430	7-421 thru 7-442	
Motor Circuit Calculations	B-21			430		
Lighting Fixtures	B-22			410 402		
Swimming and Wading Pools	B-23			680		
Cranes, Hoists, Elevators, Dumb-waiters, and Escalators	B-24			610 620	9-357 thru 9-374	
Emergency Systems	B-25			750 700		
Mobile Homes, Recreational Vehicles, and Parks	B-26			550 551		
Sample House Plans	B-27					Blueprint Enclosed
Outlet Circuiting	B-28					Blueprint Enclosed

ELECTRICAL SYSTEMS

DESIRED RESULTS:

1. To review reasons for providing separate circuits for lamps and motors.
2. To be able to sketch and trace various three-wire Delta and four wire Wye systems.

INTRODUCTION:

There are several systems that may be used for distributing electrical energy over the various arrangement of circuits. It is generally not good practice to supply lamps and motors from the same circuit unless the motors are small, fractional horsepower sizes.

Most power utility companies require a three-phase service installation when the connected motor load is in excess of 5 horsepower. Most three-phase motors of one horsepower or larger are cheaper than single-phase motors of equal rating. Furthermore, the three-phase motor is easier to maintain than a single-phase motor. The three-phase motor does not have a centrifugal switch or a commutator that require a great deal of maintenance.

PRESENTING THE LESSON:

Discuss:

1. A Wye connection.
2. A Delta system.
3. Discuss line and phase voltages and current relationships of each system.
4. Give applications of Wye and Delta connections
   a. Generators, motors, and transformers.
   b. The three and four wire transmission lines.

APPLICATION:

Have the students complete the Assignment Sheet.

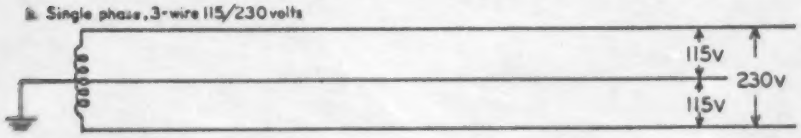
CHECKING AND FOLLOW-UP:

Check the answers.

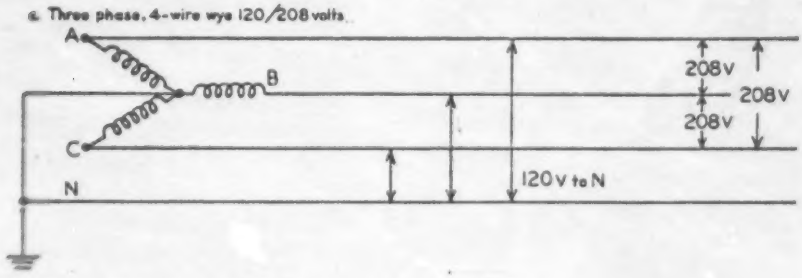
TYPES OF A.C. DISTRIBUTION 600 VOLTS OR LESS

a. Single phase, 2-wire, 115 volts

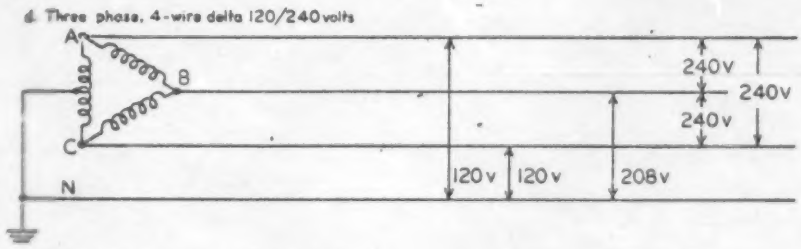
b. Single phase, 3-wire 115/230 volts



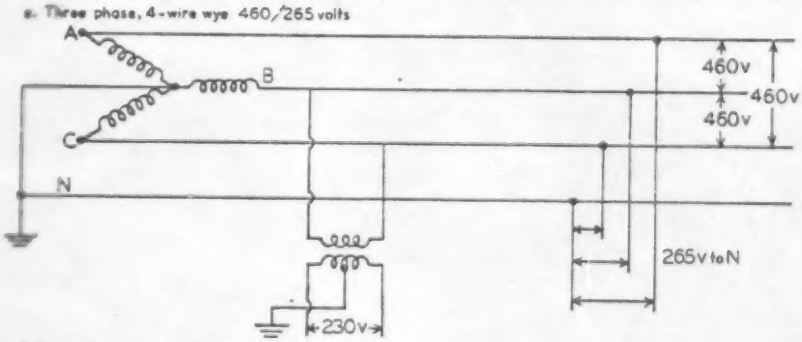
c. Three phase, 4-wire wye 120/208 volts



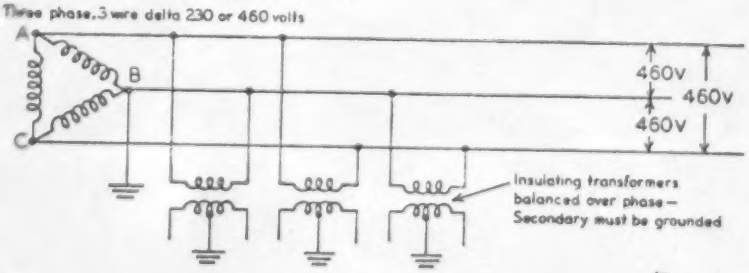
d. Three phase, 4-wire delta 120/240 volts



e. Three phase, 4-wire wye 460/265 volts



f. Three phase, 3 wire delta 230 or 460 volts

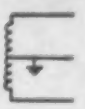


Preferred System Voltage Nomenclature, Three-Phase Systems

Industrial and Commercial Power Systems								Electrical Utility Power Systems	
Preferred Nominal System Voltage		Voltage Zones						Preferred Nominal System Voltage	
		Favorable Zone		Tolerable Zone					
		Minimum		Maximum		Minimum			
4-wire Wye	3-wire Wye or Delta							4-wire Wye	3-wire Wye or Delta
VOLTAGES AT POINT OF UTILIZATION EQUIPMENT									
Low-Voltage Systems									
208Y/120		197Y/114	(94.7%)	216Y/125	(103.8%)	193Y/111	(92.4%)	220Y/127	(105.8%)	120/208Y	
	230	210	(91.3%)	240	(104.3%)	200	(87.0%)	250	(108.7%)		230
	460	420	(91.3%)	480	(104.3%)	400	(87.0%)	500	(108.7%)		460
460Y/265(b)		434Y/250	(94.3%)	480Y/277	(104.3%)	432Y/244	(91.7%)	500Y/288	(108.7%)	265/460Y(b)	
	575	525	(91.3%)	600	(104.3%)	500	(87.0%)	625	(108.7%)		575
Medium-Voltage Systems									
	2400	2200	(91.7%)	2450	(102.1%)	2100	(87.5%)	2540	(105.8%)		2400
	4160	3810	(91.7%)	4240	(102.1%)	3630	(87.5%)	4400	(105.8%)		4160
	4800	4400	(91.7%)	4900	(102.1%)	4200	(87.5%)	5080	(105.8%)		4800
	6900	6320	(91.7%)	7050	(102.1%)	6040	(87.5%)	7300	(105.8%)		6900
	13,800	12,6 0	(91.7%)	14,100	(102.1%)	12,080	(87.5%)	14,600	(105.8%)		
PRIMARY VOLTAGES AT DISTRIBUTION TRANSFORMERS									
Medium-Voltage Systems									
		2300	(95.8%)	2500	(104.2%)	2200	(91.7%)	2600	(108.3%)		2400
		2300/4000Y	(95.8%)	2500/4330Y	(104.2%)	2200/3810Y	(91.7%)	3600/4500Y	(108.3%)	2400/4160Y	
		4600	(95.8%)	5000	(104.2%)	4400	(91.7%)	5200	(108.3%)		4800
		6900	(95.8%)	7500	(104.2%)	6600	(91.7%)	7800	(108.3%)		7200
		4600/8000Y	(95.8%)	5000/8660Y	(104.2%)	4400/7620Y	(91.7%)	5200/9000Y	(108.3%)	4800/8320Y	
		11,000	(91.6%)	12,500	(104.2%)	10,500	(87.4%)	13,000	(108.3%)		12,000
		6900/12,000Y	(95.8%)	7500/13,000Y	(104.2%)	6600/11,450Y	(91.7%)	7800/13,500Y	(108.3%)	7200/12,470Y	13,200
		12,600	(95.4%)	13,800	(104.5%)	12,100	(91.7%)	14,100	(108.3%)		
		7270/12,600Y	(95.4%)	7960/13,800Y	(104.5%)	7000/12,100Y	(91.7%)	8250/14,300Y	(108.3%)	7620/13,200Y	
		13,000	(90.3%)	14,500	(100.7%)	12,600	(87.4%)	15,000	(104.2%)		14,400
VOLTAGES AT SUBSTATIONS OR ON SUBTRANSMISSION OR TRANSMISSION SYSTEMS									
Medium-Voltage Systems									
	2400	2300	(95.8%)	2600	(108.3%)	2200	(91.7%)	2750	(114.6%)		2400
	4160	4000	(95.6%)	4500	(108.3%)	3810	(91.7%)	4760	(114.6%)		
		2300/4000Y	(95.8%)	2600/4500Y	(108.3%)	2200/3910Y	(91.7%)	2750/4760Y	(114.6%)	2400/4160Y	
	4800	4600	(95.8%)	5200	(108.3%)	4400	(91.7%)	5500	(114.6%)		4800
	6900	6600	(95.8%)	7470	(108.3%)	6320	(91.7%)	7900	(114.6%)		
		6900	(95.8%)	7800	(108.3%)	6600	(91.7%)	8250	(114.6%)		7200
		4600/8000Y	(95.8%)	5200/9000Y	(108.3%)	4400/7620Y	(91.7%)	5500/9520Y	(114.6%)	4800/8320Y	
		11,000	(91.6%)	13,000	(108.3%)	10,500	(87.4%)	13,200	(110.0%)		12,000
		6900/12,000Y	(95.8%)	7800/13,500Y	(108.3%)	6600/11,450Y	(91.7%)	7920/13,700Y	(110.0%)	7200/12,470Y	
		12,600	(95.4%)	14,300	(108.3%)	12,100	(91.7%)	14,500	(110.0%)		13,200
		7270/12,600Y	(95.4%)	8250/14,300Y	(108.3%)	7000/12,100Y	(91.7%)	8320/14,500Y	(110.0%)	7620/13,200Y	
	13,800	13,200	(95.8%)	14,950	(108.3%)	12,650	(91.7%)	15,000	(108.4%)		
		13,000	(90.3%)	15,000	(104.2%)	12,600	(87.4%)	15,500	(107.7%)		14,400
High-Voltage Systems									
	23,000	See Note 1		See Note 1		20,400	(88.7%)	25,800	(112.2%)		23,000
	27,600					24,500	(88.7%)	31,000	(112.3%)		27,600
	34,500					30,600	(88.7%)	38,000	(110.0%)		34,500
	46,000					40,000	(86.9%)	48,300	(105.0%)		46,000
	69,000					60,000	(86.9%)	72,500	(105.1%)		69,000
	115,000					100,000	(86.9%)	121,000	(105.1%)		115,000
	138,000					120,000	(86.7%)	145,000	(105.0%)		138,000
	161,000					140,000	(86.9%)	169,000	(105.0%)		161,000
	230,000					200,000	(86.9%)	242,000	(105.2%)		230,000

Note 1: For systems with nominal voltages above 13,800 volts, the designation of a "favorable zone" has been omitted as being somewhat less necessary than for the lower voltages.

Preferred System Voltage Nomenclature, Single-Phase Systems

Industrial and Commercial Power Systems								Electrical Utility Power Systems	
Preferred Nominal System Voltage		Voltage Zones						Preferred Nominal System Voltage	
2-wire	3-wire	Favorable Zone		Tolerable Zone				 3-wire	2-wire
		Minimum	Maximum	Minimum	Maximum				
VOLTAGES AT POINT OF UTILIZATION EQUIPMENT Low-Voltage Systems									
120/240	120	110 (91.7%) 110/220 (91.7%) 220/440 (91.7%)		125 (104.2%) 125/250 (104.2%) 250/500 (104.2%)		107 (89.2%) 107/214 (89.2%) 214/428 (89.2%)	127 (105.8%) 127/254 (105.8%) 254/508 (105.8%)	120/240 240/480	120

Preferred Voltage Ratings for Alternating-Current Equipment

Preferred Nominal System Voltage	Generator Rated Voltage	Transformer Secondary Rated Voltage	Transformer Primary Rated Voltage	Switchgear Nominal Rated Voltage	Capacitor Rated Voltage	Motor and Control Rated Voltage	Ballast Rated Voltage
Single-Phase Systems and Single-Phase Components Applied on Three-Phase Systems							
120	120	120	120	120		115	120
120/240	120/240	120/240	240	240	230 or 240	230	236 or 240
208Y/120, 3-phase	125/216Y, 3-phase	216Y/125, 3-phase	120	240	230 or 240	115*	120*
460Y/265, 3-phase	277/480Y, 3-phase	480Y/277, 3-phase	480	480	460 or 480		265* or 277*
Three-Phase Low-Voltage Systems							
208Y/120	125/216Y	216Y/125	208	240	216 or 230 or 240	208 or 220	208†
230	139/240Y	240Y/139 or 240	240	240	230 or 240	220	236† or 240†
460Y/265	277/480Y	480Y/277	480	480	460 or 480	440	460† or 480†
460	277/480Y	480Y/277	480	480	460 or 480	440	460† or 480†
575	346/600Y	600Y/346 or 600	600	600	575 or 600	550	
Three-Phase Medium-Voltage Systems							
2,400	1,388/2,400Y	2,400Y/1,388 or 2,400	2,400	2,400	2,400	2,300	
4,160	2,400/4,160Y	4,160Y/2,400	4,160	4,160	2,400 or 4,160	4,000	
4,800	2,770/4,800Y	4,800Y/2,770 or 4,800	4,800	13,800 or 7,200	2,770 or 4,800	4,600	
6,900	3,980/6,900Y	6,900Y/3,980	6,900	7,200	4,160 or 6,640	6,600	
7,200	3,980/6,900Y	7,200Y/4,160	7,200	13,800 or 7,200	4,160 or 7,200	6,600	
12,000	7,210/12,500Y	12,000Y/6,920	12,000	13,800	7,200 or 12,470	11,000	
7,200/12,470Y	7,210/12,500Y	12,470Y/7,200	12,000	13,800	7,200 or 12,470		
13,200	7,970/13,800Y	13,200Y/7,610	13,200	13,800	7,620 or 13,800	13,200	
13,800	7,970/13,800Y	13,800Y/7,970	13,800	13,800	7,960 or 13,800	13,200	
14,400	8,320/14,400Y	13,800Y/7,970	13,800	14,400	7,960 or 13,800 or 14,400	13,200	

* Line-to-neutral rating.
† Line-to-line rating.

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ALTERNATING CURRENT INSTRUMENTS

DESIRED RESULTS:

1. To review what the apprentice has found out about how current, voltage, and resistance can be measured.
2. To become more familiar with the types of alternating current instruments.

INTRODUCTION:

You know that an electric current is the movement of "free electrons" in a conductor. We have learned that an electric current does not begin to flow all by itself; there must be a source of electrical force to move the "free electrons" through the material. We must use instruments to measure the current, voltage, and resistance. Now let us look again at what you have studied and observed concerning the units of measurement and the correct use of the instruments.

PRESENTING THE LESSON:

1. Discuss how a lamp current is measured with an ammeter connected in series, how small currents are measured in milliamperes and microamperes, and how these units of current are changed to amperes.

2. Discuss meters for measuring voltage that have ranges in microvolts, millivolts, volts, and kilovolts. Review of voltage units and the changing of voltage units.

3. Discuss the ohmmeter and how it measures resistance. Review the various units of resistance. Review the various units of resistance and their relation to the basic unit--ohm.

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers on the Assignment Sheet.

UNCLE SAM WANTS
ELECTRICAL SAFETY TOO.

A. C. INSTRUMENTS

GENERAL INFORMATION CONCERNING A. C. INSTRUMENTS AND THEIR USE

1. When using an Ohmmeter be sure that the circuit is dead.
2. When using a Multi-meter be sure the Selector Switch is set for what you want to check.
3. Never exceed the Unit of Meter scale. Always start at the highest multiplier and work down.
4. Never connect a Voltmeter in series with a load. It has a high Internal Resistance and will burn up if connected in series.
5. Never connect an Ammeter parallel. It has a low internal resistance.

PRINCIPLES AND TYPES OF TRANSFORMERS

DESIRED RESULTS:

1. To attain an understanding of how the voltage of a source of supply (primary coil) can be used to induce a current in another coil (secondary).
2. To acquaint the students with a few of the many types of transformers.

INTRODUCTION:

The electrical principles set forth in this lesson apply specifically to transformers and indirectly to motors and electronic circuits. Discussion of the operating principles and simple demonstrations of the transformer action are necessary if a thorough understanding of this important device is to be acquired.

It will help the class to point out some specific local applications of each common type of transformer. Discuss with them the various types.

The student should read all the material listed in the references for this lesson and learn how to find this information in the future. The questions are selected to require him to read about the more common aspects of this subject.

PRESENTING THE LESSON:

A. When A.C. flows through a coil, E.M.F. is induced in the coil or an alternating magnetic field is generated around the coil.

1. E.M.F. is induced in a coil and is called self-induction when:

   a. The coil is moved through a magnetic field.
   b. The field is moved through the coil.
   c. The circuit of the electromagnet supplying the magnetic field is open and closed.

2. Another way is to vary the magnetic flux of the core in a coil.

3. Use a bar magnet to vary induced flux.

4. Explain other uses of induction coils--as telephone circuits, "neon" signs, step-up voltage supply.

B. The E.M.F. generated in the second coil is called the "E.M.F. of Mutual Induction," known as transformer action. Both induction coils and transformers operate by the principle of mutual induction. Point out that:

1. The "induction" coil is really a kind of transformer or voltage changer.

2. A transformer has a primary and a secondary wound on a core of magnetic material.

3. The secondary of an induction coil always has more turns than the primary.

4. A transformer secondary may have more or fewer turns than the primary, depending on whether the voltage is to be increased or decreased.

5. An induction coil has an open core. (The core ends do not form a complete magnetic path.)

6. A transformer has a closed core. (The core forms a complete magnetic path.)

7. Transformers may be used to decrease as well as increase voltage by the mutual induction of their windings.

C. Two kinds of transformers are the step-up and the step-down. Point out that:

1. Both have a primary and a secondary winding.

2. The step-up transformer has more turns of wire in its secondary than in its primary winding, thus, a higher voltage is produced in the secondary.

3. A step-down transformer has fewer turns in the secondary than the primary, thus, a lower voltage is produced in the secondary. Examples, a pole transformer, a bell transformer, or a toy transformer.

D. The voltage output of a transformer depends on ratio of primary to secondary coil turns. Point out that:

1. The voltage of the secondary of a transformer has the same ratio to the primary voltage as the number of secondary turns has to the number of primary turns. Stated as an equation:

$$\frac{\text{Secondary voltage}}{\text{Primary voltage}} = \frac{\text{Secondary turns}}{\text{Primary turns}}$$

2. Demonstrate this equation in proportion by working several problems on the chalkboard.

E. A current that flows in one direction and then in another is called an alternating current.

A transformer ordinarily has an alternating current flow through its primary and always has an alternating current induced in its secondary.

DISCUSS:

1. The efficiency of a transformer.
2. The service conditions under which a transformer should be able to carry its rated load.
3. Classes of transformers.
4. Methods of cooling.
5. Methods of mounting.

NOTE: It should be explained that "iron and copper" losses in transformers (as known in the electrical trade) is called hysteresis. In magnetic material, as iron, a lagging in the values of resulting magnetization is due to a changing magnetizing force. These losses, expressed in watts, are expended as heat and perform no useful work.

APPLICATION:

Have the students work and hand in assignment sheet for checking in class. Give individual help where needed.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

PRINCIPLES AND TYPES OF TRANSFORMERS

The basic theory of transformers will be found in your reference texts along with appropriate illustrations and schematic drawings. These lessons should help you to understand more about the principles of operation, the construction and the installation of the transformers in common use. Be sure to study thoroughly the assigned references found in the American Electrician's Handbook and other references.

This lesson should help you to understand the electrical principles as they apply to transformers. This knowledge will in turn help you to become a valuable mechanic on the job when there are transformers to be installed.

You will study how the voltage of a source of supply (primary coil) can be used to induce a current into another coil (secondary). This is accomplished by means of mechanical movement through the electromagnetic field or the use of alternating current. Thus the transformer is an inductive device used in alternating current distribution and changes the voltage to higher or lower amounts where needed. As you have learned, a current that flows in one direction and then in another (reversing) is called an alternating current. A transformer ordinarily has an alternating current flow through its primary coil and always has an alternating current induced in its secondary coil. It is doubtful if there would be an electrical industry if the transformer principle had not been discovered and developed.

The lesson concerns itself with some of the many types of transformers. Transformers are designed for many different uses and frequencies. The type of transformer you will be most concerned with is the power supply transformer. While there are many types you probably will never see on the job, the types studied here are very common and should be familiar to every electrician.

SINGLE PHASE TRANSFORMERS

DESIRED RESULTS:

To learn the basic facts needed to hook up a single phase transformer.

INTRODUCTION:

Transformer connections seem to be a complicated subject to many electricians. The student must learn the basic facts of the simple single-phase connections if he expects to understand the three-phase connections later.

PRESENTING THE LESSON:

The electrician will not hook up a transformer every day and he should not ask someone else to show him how to do the work.

Discuss how to make the connections. Have the students draw transformer connections on the notebook paper without help of the book.

APPLICATION:

Have the students complete the questions on the assignment sheet in class. Give individual help where needed.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

THREE-PHASE TRANSFORMERS

DESIRED RESULTS:

To acquaint the student with the technical or the theory and practice of three-phase transformer connections.

INTRODUCTION:

This lesson concerns technical information about transformer connections. The student should know facts contained in this lesson in order to make schematic drawings of actual connections. Have the students pay particular attention to the voltage and current relationships in wye and delta connections. These relationships apply to other devices such as generator and motor coils. Three-phase transformer connections have become so varied and complicated that it is impossible for a student electrician to become completely familiar with the subject, or to analyze without diagrams many of the problems that arise. However, a basic knowledge and understanding of simple transformer connections is not only essential from a standpoint of know-how but also is necessary for personal safety.

PRESENTING THE LESSON:

There are several basic transformer connections that the apprentice must memorize and be able to recognize at first glance in an actual transformer set-up and in wiring diagrams. These basic connections for three-phase work are delta (Δ) and wye (Y) for three and four wire systems. Present the advantages and disadvantages. Discuss voltage and current on the windings of a delta-delta connected transformer and a wye-wye connected transformer. In connecting large transformers in parallel, they will operate satisfactorily with their low and high-tension windings connected to the same circuits provided they have the same (1) ratio of transformation, (2) voltage rating, and (3) approximately the same regulation. Discuss advantages of the wye connected primary. Discuss disadvantages of the open delta transformer connection. Discuss cost of transformer connections.

APPLICATION:

Have the students complete the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers on the assignment sheet.

SPACE HEATING

DESIRED RESULTS:

1. To study the requirements of the N. E. Code concerning installation of fixed space heating.

2. To learn the various ways fixed space heating equipment shall be installed for approval.

INTRODUCTION:

All fixed electric space heating equipment shall be installed in an approved manner. The equipment shall be of a type approved for the purpose and location where installed. The heating equipment may be heating cable, unit heaters, boilers, central systems, or other approved fixed electric space heating equipment.

This lesson does not cover process heating and room air conditioning. Fixed electric space heating equipment using a sealed (hermetic-type) motor compressor shall comply with Article 440 of the N. E. Code. Any space heating equipment for use in hazardous locations shall be installed to conform with Articles 500 through 517.

PRESENTING THE LESSON:

After the students have studied the assignment and looked up and answered the questions on the worksheets, the instructor should point out the main points of the N. E. Code concerning space heating. A discussion on the subject is recommended to compare Electric Space Heating with other forms of heating and to show methods of installation.

It may be desirable to figure the cost of a system for a modern home or office space. The apprentice will get acquainted with the equipment and how to install it.

CHECKING AND FOLLOW-UP:

When the students have completed the questions on the worksheet, they should be checked.

DE-ICING AND SNOW MELTING EQUIPMENT

DESIRED RESULTS:

1. To become acquainted with electrically energized heating units, panels and cables used for de-icing and snow melting.

2. To learn how to install de-icing and snow melting equipment according to the N. E. Code.

INTRODUCTION:

The first units of electrically energized heating units, panels, and cables were embedded in driveways, walks, steps, and on streets that frequently iced near dangerous intersections. In these installations all requirements of the Code shall apply where applicable.

NOTE: Fixed outdoor electric de-icing and snow melting equipment shall be: (1) considered as continuous load for sizing branch circuits, and (2) installed according to Sec. 210-24.

PRESENTING THE LESSON:

Call to the attention of the apprentice that this special type equipment (units, panels, and cables) are fabricated and supplied by the manufacturer and should not be altered. Except that the non-heating leads may be shortened if the marking specified in Section 426-26 is retained. Units without NAME PLATES shall not be installed.

Point out the other Code requirements that may be different than regular installations. Stress the markings, junction boxes, and grounding methods.

The installations must be inspected and approved before being covered.

CHECKING AND FOLLOW-UP:

Check the completed worksheets.

GENERAL INSTALLATION PROVISIONS

DESIRED RESULTS:

To acquaint the apprentice with the general installation provisions required or permitted by the "Code" for electric wiring and equipment.

INTRODUCTION:

The requirements set forth in this section of the Code are general in nature and must be considered whenever an electrical installation is made. These provisions apply to all wiring and equipment installations unless specifically exempted by other sections of the Code. Therefore, the students should learn them well. Be sure that they study the entire article and not just find the answers to the questions.

It should be clearly understood that the apprentice wireman is not expected to memorize the contents of either the National Electrical Code, State and Local Safety Orders or Ordinances.

PRESENTING THE LESSON:

1. Study the definitions of the following terms, which are listed in Article 100 of the NEC: accessible, approved, concealed, device and enclosed.
2. Study the Mandatory and Advisory Rules and the use of the words "shall" and "should."
3. Give attention to sections concerning conductors, equipment, and connections to terminals 110-6 thru 110-15.

APPLICATION:

Have the class answer the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

GROUNDED CONDUCTORS

DESIRED RESULTS:

To acquaint the apprentice with the code concerning Grounded Conductors.

INTRODUCTION AND PRESENTATION:

The subject of "grounding" is very important in our work as electricians. Proper grounding insures safety for life and property. There are two general headings or types of grounding; namely, equipment and system grounding. This assignment will introduce you to the many rules and requirements for this subject. This section of the Code should be studied very carefully. A "system ground" is a connection to ground from one of the current carrying conductors of a distribution system or of an interior wiring system. An "equipment ground" is a connection to ground from one or more of the non-current carrying metal parts of the wiring system. The term equipment used here includes all such metal parts as metal conduit and raceways, metal armor of cables, outlet boxes, switch boxes, and metal motor frames. The grounding conductor may be attached to the nearest cold water pipe.

All interior wiring systems, except as provided in sections of the Code, shall have a grounded conductor. This conductor shall be identified throughout the system except as explained in the section of Code called "Unidentified Circuits." In some hazardous locations, such as hospital operating rooms, it may be desirable to install ungrounded circuits. Such ungrounded circuits must be connected to a system which is provided with a contact indicating a device that will warn the occupants of a faulty ground.

1. Study the definitions for the following terms which are listed in Article 100 of NEC: Ground, Grounded, Grounded Conductor, Grounding Conductor, Equipment.
2. Study the assigned sections of the Code very carefully.
3. Stress any particular applications noted in sections of this article which are vital in your area.

APPLICATION:

Have the students complete the answers to the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

GROUNDING

DESIRED RESULTS:

1. To acquaint the apprentice with the Code regulations for the protection of electric installations by grounding.

2. To understand the difference between "system grounds" and "equipment grounds," and how to ground them.

3. To study the methods of grounding and the sizes of conductors used.

INTRODUCTION:

Protection of electric installations by grounding is very important work for the electrician. Insulation, isolation, and guarding are suitable alternatives under certain conditions. A good example of the need in some installations for isolated or insulated ungrounded circuits is covered in the Code section for hospital operating rooms.

PRESENTING THE LESSON:

Circuits are grounded for the purpose of limiting the voltage upon the circuit which might otherwise occur through exposure to lightning or other voltages higher than that for which the circuit is designed; or to limit the maximum potential to ground due to normal voltage.

Give examples of grounding systems encountered:

a. Transformer grounding.

b. An interior wiring system grounded at the service entrance.

c. System with neutral ungrounded, with voltages to ground with an accidental ground on one conductor.

d. Instrument transformers, relays, and switchboards.

APPLICATION:

Have the students complete the assignment sheets for this lesson.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

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BRANCH CIRCUITS

DESIRED RESULTS:

To acquaint the apprentice with the requirements of the Code concerning branch circuits.

INTRODUCTION:

Most of the electrical work to be done on any job will be concerned with Branch Circuits. The apprentice should become familiar with the requirements of the Code concerning these circuits. To know these requirements and carry them out on the job will become the electrician's "bread and butter." The apprentice should study this section carefully before attempting to answer the questions on the assignment sheet.

PRESENTING THE LESSON:

1. Study the definitions for the following terms listed in Article 100 of the NEC: Branch Circuit, Branch Circuit (Appliance), Branch Circuit (General Purpose), Branch Circuit (Individual).

2. Discuss:
   (a) The scope of branch circuits.
   (b) Exceptions to the provisions in Article 210.
   (c) Classification of branch circuits.
   (d) What is a Multi-Wire Branch Circuit?
   (e) What "Color Code" is required for a five-wire branch circuit?
   (f) What is a Heavy-Duty lampholder?

3. What is meant by "Adequate Wiring"?
   (a) Discuss the minimums required by the Code.
   (b) Name the two handbooks that contain data on the design of adequate wiring.

4. Review the Calculation of Load
   (a) For General Lighting.
   (b) Other outlets supplying specific appliances and heavy-duty lampholders.
   (c) Additions to existing installations.

APPLICATION

After studying and reviewing the Code requirements, have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

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APPLIANCES

DESIRED RESULTS:

1. To determine the load that branch circuits shall conduct to insure safe operation of appliances.

2. To become acquainted with the classes of appliances and how to install circuits to insure safe operation.

INTRODUCTION:

This lesson shall apply to electric appliances used in any occupancy. Equipment shall be of a type approved for the purpose and location where installed. Call attention to the fact that no live parts shall be exposed on appliances except for toasters, grills, etc. Appliances for use in hazardous locations shall be installed to conform to Articles 500 through 517. The requirements of Article 430 apply to the installation of motor-operated appliances.

The rating of an individual branch circuit shall not be less than the marked rating of the appliance or the marked rating of an appliance having combined loads.

APPLICATION:

Have the students discuss typical installations to be used locally. How are flexible cords made and give the requirements for their use on appliances.

Have the student answer the questions on the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers.

FEEDERS

DESIRED RESULTS:

To acquaint the apprentice with the determination of the minimum sizes of feeder conductors necessary for safety.

INTRODUCTION:

This topic is concerned largely with feeder requirements for apartment houses and for stores. Although the basic rules are the same as for the single dwelling, the additional rules are more complex. For example, it is often the job of the electrician to install the single-phase three-wire service entrance for an apartment building. He has the problem of determining the size of the conductors and conduit for the service entrance.

It is also necessary to determine the size of the subfeeders for each apartment. Of particular interest in this assignment is the method for determining demand load for groups of electric ranges in an apartment house. It is not necessary to memorize the requirements listed for groups of ranges or other fixed appliances. It is wise to spend enough time studying the notes appended to the table to make certain that methods for determining service and feeder demand factors are thoroughly understood.

PRESENTING THE LESSON:

Study the following sections: Feeder size; Normal voltage and Voltage drop; Calculation of Load; Computation of Feeder Sizes and Common Neutral Feeder.

After the students have studied the above sections, the instructor should go through each topic with them and point out the important items.

APPLICATION:

Have the students fill in the answers to questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

SERVICES

DESIRED RESULTS:

1. To understand the connections of standard single-phase, three-wire service entrances.
2. To understand the requirements of the National Electrical Code and power utility companies for a typical single family dwelling.

INTRODUCTION:

In general, a building shall be supplied through only one set of service conductors. A building may be supplied by two or more service drops when there is good reason for this arrangement. (See Sections 230-2)

The service entrance for most residential installations is a single-phase, three-wire service. The middle wire is called the neutral wire and is grounded; it is identified by the white insulation. The two outside wires are known as the hot wires. The voltage between the neutral wire and either of the hot wires is 115 volts, and the voltage between the two hot wires is 230 volts.

In these modern times with the many electrical appliances, it is a definite advantage to have both 115 and 230 volts available. Many types of loads such as electric water heaters, electric ranges, and fractional horsepower motors operate on 230 volts. The higher voltage is preferable because heating appliances and motors will take less current. This permits the use of smaller wires, results in less voltage drop and less wasted power.

PRESENTING THE LESSON:

After the students have read Article 230, the instructor should point out the fundamental rules of the National Electrical Code. The rules concern the calculations affecting the service entrance switch, service entrance conductors, and grounding should be called to their attention.

Using the information sheets provided the students, review how to determine the number of circuits, the rating in volts and amperes, and the wire sizes for a typical, single family dwelling.

APPLICATION AND CHECKING AND FOLLOW-UP:

The students will complete the answers on the assignment sheets for this lesson. Then, check the answers.

SERVICES FOR A TYPICAL DWELLING

A typical application for a 115/230 volt, single-phase, three wire service installation in a single family dwelling will be considered. It is the intent to give the apprentice the fundamental rules of the National Electrical Code insofar as they concern the calculations that affect the service entrance switch, service entrance conductors, and grounding. The branch circuits supplying the various items of electrical equipment will be discussed briefly. Since the metering of the electrical space heating equipment as well as electric water heaters varies with different power companies, the apprentice should check the requirements in the area.

The building under consideration will be a three-bedroom residence with an area of 1500 square feet.

A. THE FOLLOWING APPLIANCES ARE SCHEDULED FOR THIS HOME:

1. 3-kw water heater
2. 4.7-kw clothes dryer
3. 8 ampere-230-volt air conditioner
4. 11.1 ampere-115-volt dishwasher
5. 4-kw wall-mounted oven
6. 6-kw counter-mounted cooking unit
7. 7.5 ampere-115-volt garbage disposal
8. space heating unit in each of 6 rooms rated 2-kw each

B. Calculations:

1. <u>Determine the Number of Lighting Circuits</u>

Calculate the load based on the "watts per square foot" method.
1500 sq. ft. x 3 watts per sq. ft. - 4500 watts

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4500}{115} = 39.1 \text{ or } 40 \text{ amperes}$$

Generally, 15-ampere lighting circuits are installed in residential buildings using No. 14 AWG conductors. Some electrical specifications require No. 12 AWG conductors as a minimum on all circuits. Then $\frac{40}{15} = 2$ plus or 3

Note: In a residence of this type, there may be as many as 60 outlets. Most electricians prefer to limit the number of outlets per circuit to 8 or 10, thus there would be 6 circuits installed.

2. Small Appliance

Most electricians prefer to run three 20 ampere circuits for small appliances to be used in the kitchen, laundry, pantry, dining room, and breakfast room areas. It is a code requirement to install a separate 20 ampere circuit for the laundry outlet and divide the outlets in the kitchen and dining room area between the other two at 20 ampere circuits. The use of No. 12 wire instead of No. 14 wire to minimize the voltage drop, improves the performance of the appliances and lessens the danger of overload.

3. Clothes Dryer

The electric clothes dryer is rated 4.7 kw at 230 volts. The load value in watts if 4700.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4700}{230} = 20.4 \text{ amperes}$$

The circuit to the dryer will be a 30 ampere 115/230 volt, 3 wire circuit of two No. 10 AWG conductors and one No. 12 AWG for the neutral conductor. The neutral may be smaller than the phase wires because it carries only the current of the motor and the light.

4. Air Conditioning

The load is 8 amperes x 230 volts = 1840 watts. It will be connected to a 15 ampere, 230 volt circuit with No. 14 AWG conductors. Circuits for air conditioners must conform to the provisions of the Code.

5. Dishwasher

The load is 11.1 amperes x 115 volts = 1276 watts. This unit will be supplied by a separate 15-ampere circuit using No. 14 AWG wire.

6. Garbage Disposal

The load is 7.5 amperes x 115 volts = 852 watts. This circuit will be supplied by a separate 15-ampere circuit which requires No. 14 AWG wire.

7. Wall-Mounted Oven

The oven is rated 4-kw at 115/230 volts and will be connected to a separate circuit. The load value in watts is 4000.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{4000}{230} = 17.4 \text{ amperes}$$

According to the table No. 12 AWG conductor may be used for this circuit. NEC - 250-260, Ground with No. 10.

8. Counter-Mounted Cooking Unit

The surface cooking unit is rated 6 kw at 115/230 volts and will be connected to a separate circuit consisting of three No. 10 AWG conductors supplied by a 30-ampere, 2 pole overcurrent device.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{6000}{230} = 26 \text{ (approx.) amperes}$$

Note: The Code permits the use of one 50-ampere circuit to supply these two units, provided the individual taps to the 50-ampere circuit are not longer than necessary for servicing.

9. Electric Space Heating

Six 2 kw electric space heating units will be installed with a thermostat which provides individual room control for heating purposes. Also, it is necessary that there be four or more individually controlled electric space heating units in order to apply certain demand factors permitted by the Code used in calculating service-entrance capacity. Each of these units is rated at 2 kw and 230 volt circuit.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{2000}{230} = 8.7 \text{ amperes}$$

Each separate unit will be connected to a separate 15-ampere, 230 volt circuit using No. 14 AWG wire.

10. Water Heater

The water heater in this residence is rated at 3-kw.

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}} = \frac{3000}{230} = 13 \text{ amperes}$$

Connected for unlimited demand, the maximum current would be 13 amperes and No. 14 AWG could be used. However, for a load that so closely approaches the maximum current-carrying capacity of No. 14 AWG, most electricians would install No. 12 AWG (20 ampere) and connect it to a 15 ampere, 230 circuit.

Note: Consult local utility for proper connections of water heaters because some require a special "off peak" meter and others use special methods to cover the power consumption.

SUMMARY OF SERVICES FOR 1500 SQ. FT. DWELLING

Use of Circuits	No. of Circuits	Rating		Wire Size
		Volts	Amperes	AWG
General Lighting	6	115	15	14
Small Appliances	3	115	20	12
Garbage Disposal	1	115	15	14
Dishwasher	1	115	15	14
Dryer	1	115/230	30	10
Oven	1	115/230	20	12
Counter Cook Top	1	115/230	30	10
Air Conditioner	1	230	15	14
Water Heater	1	230	15	12
Space Heat	6	230	15	14

Service Entrance Switch

To accomodate the number of circuits listed in the summary, a 200-ampere panel will be installed. This panel will contain all of the required branch circuits plus a 200-ampere main pullout in one enclosure. This type of enclosure is approved by Underwriters' Laboratories, Inc. and should meet the Code requirements in most localities.

Ground Connection

The Code requires interior-alternating-current systems to be grounded. This is done by running a wire from the neutral connection in the main service switch or meter to a water pipe. Exceptions to the rule are specified in the Code.

TEMPORARY SERVICES

DESIRED RESULTS:

1. Given a problematic situation concerning temporary wiring, the student will be able to locate the related section in the National Electrical Code book.

2. The student will be able to identify the equipment and supplies required for installing temporary feeders, branch circuits, and receptacles.

INTRODUCTION:

The Code provisions applicable for Temporary Electrical Power and lighting wiring methods are found in Article 305. These requirements may be of a class less than would be required for a permanent installation. Except as specifically modified in the Article 305, all other requirements of this Code for permanent wiring shall apply to temporary wiring installations.

PRESENTING THE LESSON:

Temporary services may be used during the period of construction, remodeling, or demolition of buildings, structures, equipment, or similar work.

Temporary wiring installations may be used for a period not to exceed 90 days for Christmas decorations, carnivals, and similar purposes.

Have the students research the Code for general services, feeder protection, origin of branch circuits, grounding, and disconnecting means for temporary wiring.

APPLICATION:

The students will complete the answers on the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers.

OUTSIDE BRANCH CIRCUITS

DESIRED RESULTS:

1. To understand the meaning and function of outside branch circuits.
2. To become acquainted with the Code requirements for outside branch circuits and feeders.

INTRODUCTION AND PRESENTATION:

The requirements of this article shall apply to electrical equipment and wiring for the supply of utilization equipment located on or attached to the outside of public and private premises or run between buildings, structures or poles. It does not apply to wiring for signs and outside lighting, nor to equipment or wiring of an electric utility used in the exercise of its function as a utility.

These Code rules are not intended to regulate overhead distribution lines except as follows:

1. The safety of wiring systems in, on, or between buildings is affected.
2. Where on the account of the proximity to a building, the safety of the building and its occupants is affected.

Rules are included here for wiring on the exteriors of buildings and on premises such as athletic fields, parking lots, and spaces temporarily used for fairs and carnivals.

Note the application of other Code Articles, including additional requirements to specific cases of equipment and conductors.

Review the types of conductors, insulation and minimum size required for branch circuits. Discuss methods of supporting open conductors; clearance from ground; clearance from buildings for conductors not in excess of 600 volts.

What type lampholders are required and where should the lamps be located for outdoor lighting?

APPLICATION:

Have the students complete the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the Assignment Sheet.

D. C. MOTORS AND GENERATORS

DESIRED RESULTS:

1. To acquaint the students with the principal types of D. C. motors and generators and where they are used.

2. To learn how to install or connect conductors with the motors used under special conditions.

INTRODUCTION AND PRESENTING THE LESSON:

D. C. motors and generators are mostly used as emergency systems in health care facilities, stand-by power, and generation systems.

1. Call attention to the many definitions 517-2 of the Code concerning Health Care Facilities.

2. Discuss the Emergency System in Code 700 and Life Safety Branch Code 517, Critical Branch Code 517.

3. Review how the equipment systems shall be installed - Reference 517.

4. Discuss wiring and equipment within hazardous areas in health care facilities such as inhalation anesthetizing locations, etc.

5. Explain general wiring, sources of power, installation and maintenance of equipment in Emergency Systems.

6. Discuss the installation, operation and maintenance of circuits, systems and equipment intended to supply on-site generated power (to selected loads, automatically or manually, in the event of failure of the normal source of electrical service).

APPLICATION AND CHECK-UP:

The students should complete the questions on the worksheet. They should be checked.

Motor enclosures
(NEMA designations)*

OPEN

General purpose: Ventilating openings permit passage of external cooling air over and around the windings of the machine.

Drip-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from the vertical.

Splash-proof: Ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle not greater than 100 degrees downward from the vertical.

Guarded: Openings giving direct access to live or rotating parts (except smooth shafts) are limited as to size by the design of the structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with such parts.

Semi-guarded: Part of the ventilating openings, usually in top half, are guarded as in a "guarded machine," but others are left open.

Drip-proof fully guarded: A drip-proof machine with ventilating openings as in a "guarded machine."

Externally ventilated: A machine which is ventilated by means of a separate motor-driven blower mounted on machine enclosure. Mechanical protection may be as defined above.

Pipe ventilated: Openings for admission of ventilating air are so arranged that inlet ducts or pipes can be connected to them.

Weather-protected: Type I: Ventilation passages are so designed as to minimize the entrance of rain, snow and airborne particles to the electrical parts. Type II: Ventilating passages at intake and discharge are so arranged that high-velocity air and airborne particles blown into the machine by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electrical parts.

Encapsulated windings: An alternating-current squirrel-cage machine having random windings filled with an insulating resin which also forms a protective coating.

Sealed windings: An alternating-current squirrel-cage machine making use of form-wound coils and having an insulation system which, through the use of materials, processes, or a combination of materials and processes, results in a sealing of the windings and connections against contaminants.

TOTALLY ENCLOSED

Nonventilated: Enclosure prevents free exchange of air between inside and outside of case, but not airtight.

Fan-cooled: Equipped for exterior cooling by means of a fan or fans, integral with machine, but external to the enclosing parts.

Fan-cooled guarded: All openings, giving direct access to fan, are limited in size by design of structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with fan.

Explosion-proof: Designed and built to withstand an explosion of gas or vapor within it and to prevent ignition of gas or vapor surrounding machine by sparks, flashes, or explosions which may occur within machine casing.

Dust-ignition-proof: Designed and built to exclude ignitable amounts of dust or amounts affecting performance or rating to prevent ignition of exterior dust on or in vicinity of enclosure.

Water-proof: Designed to exclude water applied in a stream from a hose except leakage is permitted around the shaft provided that water is excluded from oil reservoir and means of drainage is provided.

Pipe-ventilated: Openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of ventilating air.

Water-cooled: Cooled by circulating water; the water or water conductors come in direct contact with the machine parts.

Water-air-cooled: Cooled by circulating air which, in turn, is cooled by circulating water.

Air-to-air-cooled: Cooled by circulating internal air through heat exchanger which, in turn, is cooled by circulating external air.

*See NEMA Standards MG1-1.25,26,27 for additional details.

Basic motor insulation classes

Class A. Materials or combinations of materials such as cotton, silk and paper, when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil. This class of material is falling into disuse.

Class B. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (120°F-130°F).

Class F. Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (145°F-155°F).

Class H. Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests the total system can be shown to be capable of operating successfully on the machine under consideration (165°F-180°F).

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Controller enclosures

(NEMA designations)*

Type	Description	Application
1	General purpose	Indoors; atmospheric conditions normal. Provides protection against dust and light, indirect splashing—but is not dust-tight.
2	Driptight	Indoors; general-purpose enclosure; shields give protection from dripping liquids and dirt.
3	Weather-resistant (Weatherproof)	Outdoors; where exposed to rain or sleet.
4	Watertight	Outdoors; water or moisture excluded from splashing or direct stream.
5	Dust-tight	Indoors; prevents entry of dust into nonhazardous locations.
6	Submersible	For use where unit may be submerged in water.
7	Hazardous areas (Groups A-B-C-D)	For Class 1 locations containing hazardous gases; air-break contacts.
8	Hazardous areas (Groups A-B-C-D)	For use where gases are corrosive (similar to Type 7, but contacts are immersed in oil).
9	Hazardous areas (Groups E-F-G)	For use in Class II, Group E, F and G locations containing hazardous dusts
10	Bureau of Mines	For use in coal mines.
11	Corrosion-proof	For use where exposed to corrosive acid or fumes.
12	Industrial	Protects against dirt, dust, lint, fibers, flyings and oil or coolant seepage; meets JIC electrical standards for industrial equipment.

* Last revised in 1966.

SINGLE-PHASE MOTORS

DESIRED RESULTS:

To acquaint the students with the single-phase motor, how and why it operates, and its proper use on the job.

INTRODUCTION:

When it was discovered that a coil of wire induces magnetic polarity in a soft-iron core, studies were made to find out that the poles were induced into the rotor. It was discovered that two sets of poles are so induced, one by transformer action, and one by the generating action of cutting lines of force. The poles induced by transformer action were found to be the most essential to successful operation of the motor. A pole induced in the rotor through transformer action becomes active only after it has rotated far enough to be attracted toward the next stator pole ahead. This delayed action was found to be caused by the fact that induced voltages lag inducing fluxes by 90 degrees, and that current flow in a highly inductive circuit, as exists in the rotor, lags the voltage by 90 degrees.

The capacitor motor plays such an important part in the work of an electrician today that it cannot be slighted. You will be working with this motor almost daily as an electrician, so be sure to know how and why it runs. It is easy to get confused because of the different classes of capacitor motors. Learn to recognize the several classes of capacitor-start split-phase induction motors.

The repulsion motor is not nearly as popular as it was before the introduction of capacitor-start motor. Although they are being replaced in many installations today, there are a great number still in service on air compressors and other heavy starting load applications. The electrician should be familiar with this motor and its characteristics.

This lesson begins a series of study of fractional horsepower motors. These motors are named from their differences in methods of starting. One type of induction motor which incorporates a starting device is called a "split-phase" induction motor. This motor uses combinations of inductance, capacitance and resistance to develop a rotating field. Split-phase motors come only in small sizes since the special starting windings are very light, thus, the motor does not develop enough torque to start heavy loads. Remember that this type of motor is very common and you will contact it most frequently in your work.

PRESENTING THE LESSON:

1. The first type of split-phase induction motor that we will study is the capacitor-start model. Refer to the simplified schematic diagrams in your texts for a typical capacitor-start motor. There are two windings, the main winding and a starting winding which is connected in parallel with the main winding and spaced at right angles to it. The 90 degree electrical phase difference between the two windings is obtained by connecting the auxiliary winding in series with a capacitor and the starting switch. Upon starting, the switch is closed, placing the capacitor in series with the auxiliary winding. The capacitor is of such a value that the auxiliary winding is effectively a resistive-capacitive circuit in which the current leads the live voltage by approximately 45 degrees. The main winding has enough resistance to cause the current to lag the line voltage by approximately 45 degrees. The two currents are therefore 90 degrees out of phase and so are the magnetic fields which they generate. The effect is that the two windings act like a two-phase stator and produce the revolving field required to start the motor.

2. Discuss the motors and be sure that the students understand how they run. The student should be able to determine whether or not a motor should be sent to a shop, be replaced, or repair it on the job.

3. The student should obtain a clear picture of the rotating magnetic field. He should be familiar with the relationships between voltage, and torque, and starting, running, and breakdown torques in the induction motor.

APPLICATION:

Give the students time to complete the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

THREE-PHASE MOTORS

DESIRED RESULTS:

1. To review the principle of the rotating magnetic field in order to understand the three-phase motor.

2. The student should know how the motor runs and how to connect and service it.

INTRODUCTION:

Three-phase systems are widely used because they are superior to single-phase systems in many ways. These motors are smaller, simpler in construction, and have better operating characteristics than the single phase units of the same capacity. You should learn the basic ideas of the three-phase motors well in order to know what to do on the job. Since the three-phase motor is the workhorse of industry today, it is important that the apprentice knows how it runs and how to connect and service it.

PRESENTING THE LESSON:

1. Review the principle of the rotating magnetic field.
2. Discuss the general types of three-phase motors in common usage.
3. Show how the three-phase windings of a motor are placed, spaced, and connected.
4. Show the class the standard lead connections for squirrel-cage motors. Be sure that they learn these connections.
5. What can be noted about the speed of a squirrel-cage motor under varying loads.
6. Note that the direction of rotation of an induction motor is the same as that of the magnetic field.
7. Show how a three-phase motor can be reversed.
8. What is the starting torque of a pure synchronous motor?
9. How do you control the speed of a wound-rotor motor?

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

MOTOR CIRCUITS

DESIRED RESULTS:

To acquaint the student with the N.E. Code requirements in regard to motors and their installation.

INTRODUCTION:

The Code places great importance upon the proper installation of this equipment, even to the point of devoting a lengthy section to motors. Be sure that the student understands the requirements of Article 430 and how they apply on the job.

PRESENTING THE LESSON:

The students should read the reference article and class discussion should cover those sections of Article 430 not specifically touched upon by the questions on the Assignment Sheet. The student can usually answer some of the questions from general knowledge or guessing. However, if he is required to list the section number after his answer, he will read and learn more Code in studying the lesson.

APPLICATION:

Have the students look up the answers to the questions and list the section number after each.

CHECKING AND FOLLOW-UP:

Check the answers. Continue the study of Motor Circuits.

NOTE: The next lesson, B-21, consists of a work session using the problem and diagram given in the Student's Worksheets.

LIGHTING FIXTURES

DESIRED RESULTS:

To learn that the proper installation of lighting fixtures must be correct in order to be effective.

INTRODUCTION:

The technical details of the design of a lighting system are only a partial solution of the problems of satisfactory lighting operation. If a lighting system is to be effective, the installation must be correct in every respect. However, unless it is properly maintained, a system that is adequate at the time of installation will depreciate rapidly. This is equally true for natural and artificial lighting. Maintenance should not be entrusted to the average caretaker unless he is properly supervised. It should be based upon a regular, systematic schedule and include a system of reports and checks.

PRESENTING THE LESSON:

1. Call attention to the main items of installation included in Article 410 of the National Electrical Code. Include cord connected fixtures, and how fixtures are mounted that have certain sizes and weights. Factors that determine size and type of wire used in fixtures should be discussed.

2. Explain how the lighting unit for general illumination should be located symmetrically throughout the area to be illuminated.

3. Is complete uniformity of illumination desirable in all installations? Why?

4. What is the most common method of illumination and what is the reason for its popularity?

5. How much illumination (foot candles) is needed for the following: (See tables in Handbook)

   (a) Bakery
   (b) Cannery
   (c) Linotype room (printing)
   (d) Office (close work)
   (e) Textile (Cotton Spinning)

APPLICATION:

Have the students complete the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

SWIMMING AND WADING POOLS

DESIRED RESULTS:

To study the Code requirements for installing electric wiring for equipment and lighting at swimming pools.

INTRODUCTION:

The provisions of this Article apply to the construction and installation of electric wiring for equipment in or adjacent to swimming pools, and to the auxiliary equipment such as pumps, filters, and similar equipment. No electric wiring or apparatus shall be installed in the water or enclosed walls of a swimming pool, except as provided for in this article.

PRESENTING THE LESSON:

Have the students study this Article and look up any references. Discuss any questions that may arise, especially safety of certain pools. Present the definitions listed in 680-4 of this Article.

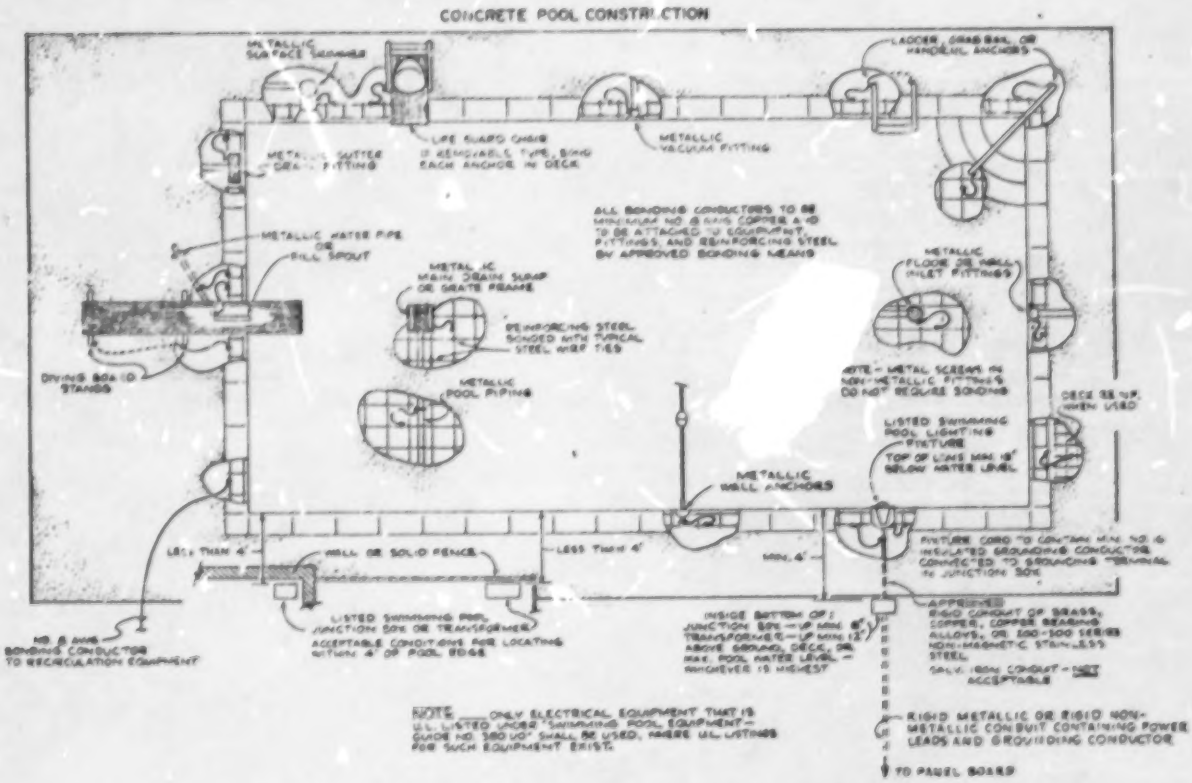
APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers to the questions.

SWIMMING POOL ELECTRICAL BONDING & GROUNDING


CONCRETE POOL CONSTRUCTION
METALLIC SURFACE SKIMMER
LIFE GUARD CHAIR IF REMOVABLE TYPE, BOND EACH ANCHOR TO DECK
METALLIC VACUUM FITTING
LADDER, GRAB RAIL, OR HANDRAIL ANCHORS
METALLIC WATER PIPE OR FILL SPOUT
ALL BONDING CONDUCTORS TO BE MINIMUM NO. 8 AWG COPPER & TO BE ATTACHED TO EQUIPMENT, FITTINGS, AND REINFORCING STEEL BY APPROVED BONDING MEANS
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
METALLIC FLOOR OR WALL INLET FITTINGS
REINFORCING STEEL BONDED WITH TYPICAL STEEL WIRE TIES
DIVING BOARD & STAND
METALLIC POOL PIPING
NOTE - METAL SCREWS IN NON-METALLIC FITTINGS DO NOT REQUIRE BONDING
DECK TO BE UP WHEN USED
LISTED SWIMMING POOL LIGHTING FIXTURE
TOP OF LENS MIN 18" BELOW WATER LEVEL
METALLIC WALL ANCHORS
LESS THAN 4'
WALL OR SOLID FENCE
LESS THAN 4'
MIN. 4'
FIXTURE CORD TO CONTAIN MIN NO 12 INSULATED GROUNDING CONDUCTOR CONNECTED TO GROUNDING TERMINAL IN JUNCTION BOX
NO 8 AWG BONDING CONDUCTOR TO RECIRCULATION EQUIPMENT
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER
ACCEPTABLE CONDITIONS FOR LOCATING WITHIN 4' OF POOL EDGE
INSIDE BOTTOM OF JUNCTION BOX - UP MIN 8" TRANSFORMER - UP MIN 12" ABOVE GROUND, DECK, OR MAX. POOL WATER LEVEL - WHICHEVER IS HIGHEST
APPROVED RIGID CONDUIT OF BRASS, COPPER, COPPER BEARING ALLOYS, OR 300-300 SERIES NON-MAGNETIC STAINLESS STEEL
SOLID IRON CONDUIT - NOT ACCEPTABLE
NOTE - ONLY ELECTRICAL EQUIPMENT THAT IS U.L. LISTED UNDER "SWIMMING POOL EQUIPMENT" SHOULD NO "SHOULD" SHALL BE USED, WHERE UL LISTINGS FOR SUCH EQUIPMENT EXIST.
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

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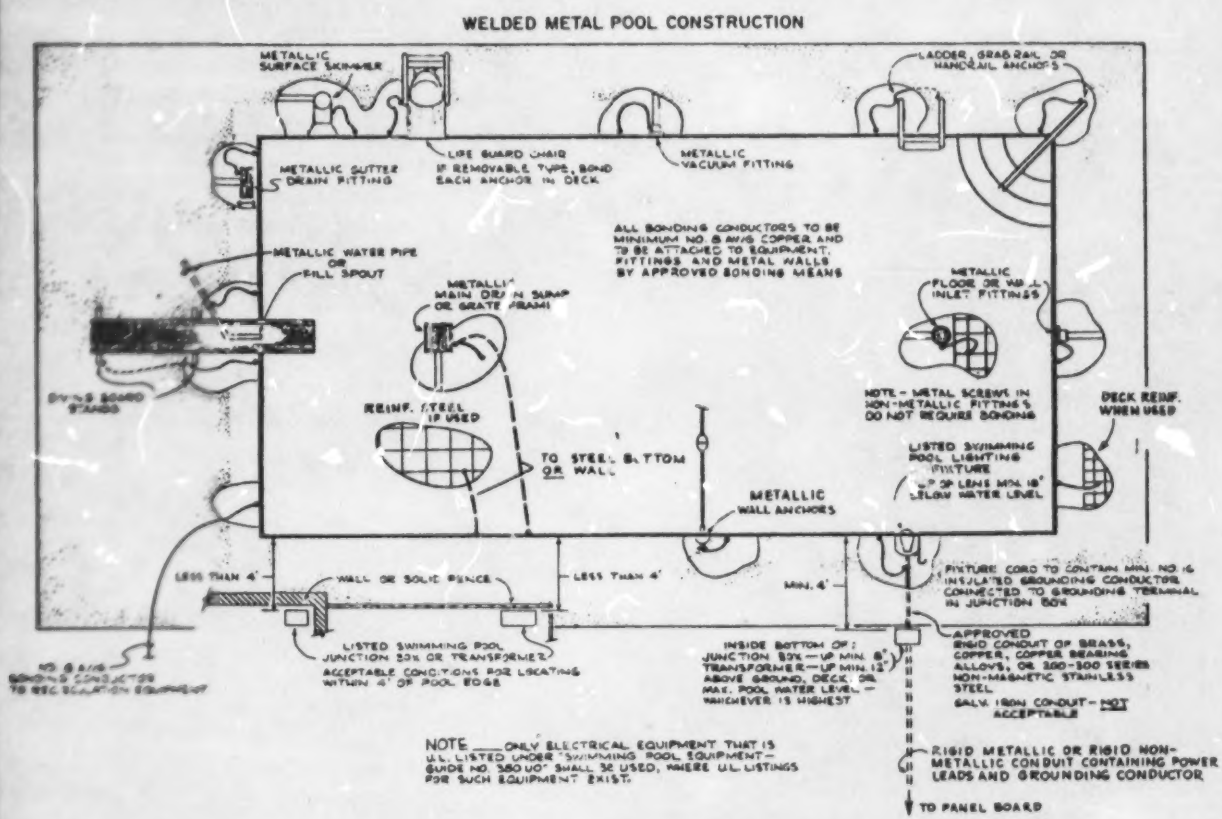
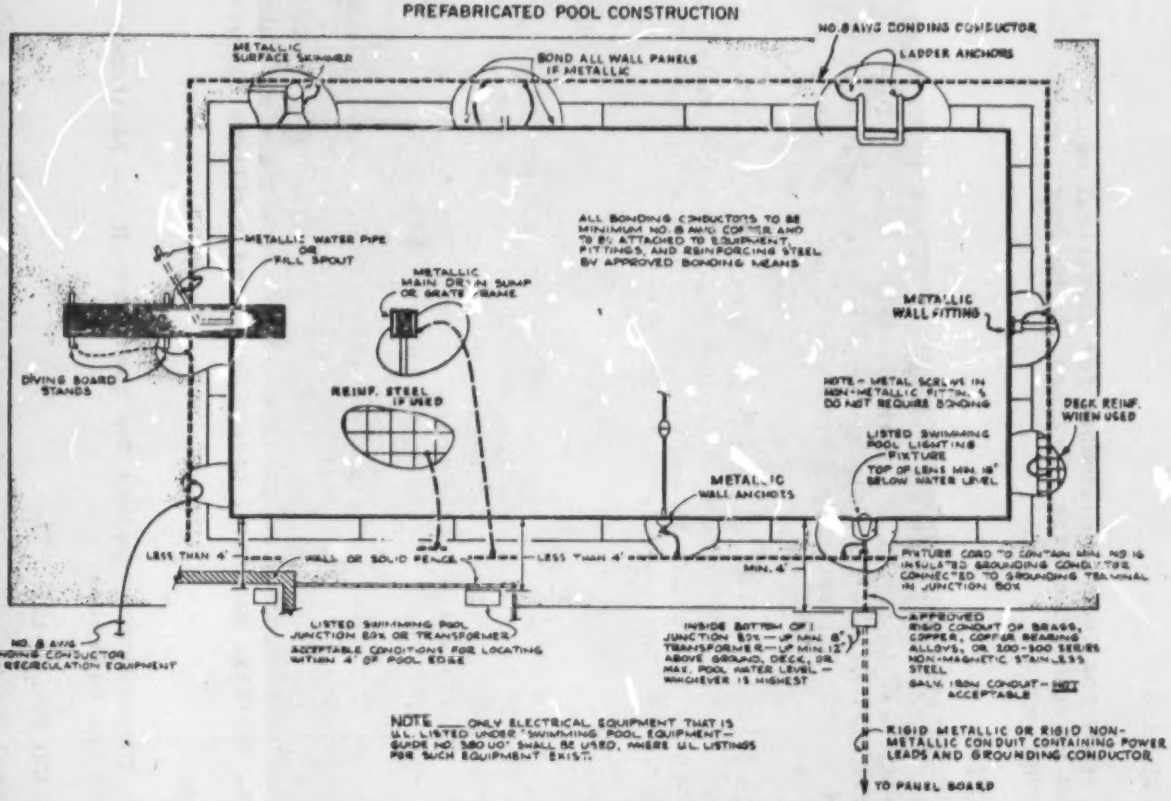
"ALL ELECTRICAL EQUIPMENT USED WITH SWIMMING AND WADING POOLS SHALL BE SUPPLIED BY CIRCUITS PROTECTED BY GROUND-FAULT CIRCUIT INTERRUPTERS."

SWIMMING POOL ELECTRICAL BONDING & GROUNDING


WELDED METAL POOL CONSTRUCTION
METALLIC SURFACE SKIMMER
LADDER, GRAB RAIL, OR HANDRAIL ANCHORS
METALLIC SUTTER DRAIN FITTING
LIFE GUARD CHAIR IF REMOVABLE TYPE, BOND EACH ANCHOR TO DECK
METALLIC VACUUM FITTING
ALL BONDING CONDUCTORS TO BE MINIMUM NO. 8 AWG COPPER AND TO BE ATTACHED TO EQUIPMENT, FITTINGS AND METAL WALLS BY APPROVED BONDING MEANS
METALLIC WATER PIPE OR FILL SPOUT
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
METALLIC FLOOR OR WALL INLET FITTINGS
DIVING BOARD STAND
REINF. STEEL IF USED
TO STEEL BOTTOM OR WALL
NOTE - METAL SCREWS IN NON-METALLIC FITTINGS DO NOT REQUIRE BONDING
DECK REINF. WHEN USED
LISTED SWIMMING POOL LIGHTING FIXTURE
TOP OF LENS MIN. 18" BELOW WATER LEVEL
METALLIC WALL ANCHORS
LESS THAN 4'
WALL OR SOLID FENCE
LESS THAN 4'
MIN. 4'
FIXTURE CORD TO CONTAIN MIN. NO 16 INSULATED GROUNDING CONDUCTOR CONNECTED TO GROUNDING TERMINAL IN JUNCTION BOX
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER ACCEPTABLE CONDITIONS FOR LOCATING WITHIN 4' OF POOL EDGE
INSIDE BOTTOM OF: JUNCTION BOX — UP MIN. 8" TRANSFORMER — UP MIN. 12" ABOVE GROUND, DECK, OR MAX. POOL WATER LEVEL — WHICHEVER IS HIGHEST
APPROVED RIGID CONDUIT OF BRASS, COPPER, COPPER BEARING ALLOYS, OR 300-300 SERIES NON-MAGNETIC STAINLESS STEEL
GALV. IRON CONDUIT - NOT ACCEPTABLE
NOTE — ONLY ELECTRICAL EQUIPMENT THAT IS U.L. LISTED UNDER "SWIMMING POOL EQUIPMENT" GUIDE NO. 380 U0" SHALL BE USED, WHERE U.L. LISTINGS FOR SUCH EQUIPMENT EXIST.
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

Reproduced Courtesy of IAEI NEWS (Permission July 13, 1972)

SWIMMING POOL ELECTRICAL BONDING & GROUNDING


PREFABRICATED POOL CONSTRUCTION
METALLIC SURFACE SKIMMER
BOND ALL WALL PANELS IF METALLIC
NO. 8 AWG BONDING CONDUCTOR
LADDER ANCHORS
ALL BONDING CONDUCTORS TO BE MINIMUM NO. 8 AWG COPPER AND TO BE ATTACHED TO EQUIPMENT, FITTINGS, AND REINFORCING STEEL BY APPROVED BONDING MEANS
METALLIC WATER PIPE OR FILL SPOUT
METALLIC MAIN DRAIN SUMP OR GRATE FRAME
METALLIC WALL FITTING
DIVING BOARD STANDS
REINF. STEEL IF USED
NOTE - METAL SCREWS IN NON-METALLIC FITTINGS DO NOT REQUIRE BONDING
DECK REINF. WHEN USED
LISTED SWIMMING POOL LIGHTING FIXTURE
TOP OF LENS MIN. 18" BELOW WATER LEVEL
METALLIC WALL ANCHORS
LESS THAN 4'
WALL OR SOLID FENCE
LESS THAN 4'
MIN. 4'
FIXTURE CORD TO CONTAIN MIN. NO 16 INSULATED GROUNDING CONDUCTOR CONNECTED TO GROUNDING TERMINAL IN JUNCTION BOX
NO. 8 AWG BONDING CONDUCTOR TO RECIRCULATION EQUIPMENT
LISTED SWIMMING POOL JUNCTION BOX OR TRANSFORMER ACCEPTABLE CONDITIONS FOR LOCATING WITHIN 4' OF POOL EDGE
INSIDE BOTTOM OF JUNCTION BOX — UP MIN. 8" TRANSFORMER — UP MIN. 12" ABOVE GROUND, DECK, OR MAX. POOL WATER LEVEL — WHICHEVER IS HIGHEST
APPROVED RIGID CONDUIT OF BRASS, COPPER, COPPER BEARING ALLOYS, OR 300-300 SERIES NON-MAGNETIC STAINLESS STEEL
GALV. IRON CONDUIT — NOT ACCEPTABLE
NOTE — ONLY ELECTRICAL EQUIPMENT THAT IS U.L. LISTED UNDER "SWIMMING POOL EQUIPMENT" GUIDE NO. 380 U0" SHALL BE USED, WHERE U.L. LISTINGS FOR SUCH EQUIPMENT EXIST.
RIGID METALLIC OR RIGID NON-METALLIC CONDUIT CONTAINING POWER LEADS AND GROUNDING CONDUCTOR
TO PANEL BOARD

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CRANES, HOISTS, ELEVATORS, DUMBWAITERS, AND ESCALATORS

DESIRED RESULTS:

To study the Code requirements for electrical equipment and wiring used in connection with elevators, dumbwaiters, escalators, and moving walks.

INTRODUCTION:

The provisions of this article apply to electrical equipment and wiring used in connection with elevators, dumbwaiters, escalators, etc. They will also apply to console lifts, equipment for raising and lowering or rotating portions of theater stages, and all similar equipment.

All wiring in the raceways and in or on the cars of elevators, etc., shall be flame-retardant and moisture-resistant insulation. The thickness of the insulation of all wiring shall be suitable for the voltage to which the wiring is subjected.

PRESENTING THE LESSON:

Have the students review Articles 610 and 620 and then study them in detail. They should note the minimum size of conductors and their installation, and the different systems in one raceway or cable and the requirements for this installation. The requirements for motor circuit conductors should be discussed.

Disconnecting means, overcurrent protection, grounding, and overspeed control should be provided.

A machine room shall be provided to secure all moving motor generator sets, driving, machines, controllers, and auxiliary control equipment.

APPLICATION:

Have the students complete the questions on the Assignment Sheet using the Code book.

CHECKING AND FOLLOW-UP:

Check the answers.

EMERGENCY SYSTEMS

DESIRED RESULTS:

1. To study the reasons for providing separate power and light emergency systems in places of assembly.

2. To acquaint the student with the requirements of the National Electrical Code that apply to emergency systems.

INTRODUCTION AND PRESENTATION:

Emergency systems are generally installed in places of assembly where artificial illumination is required, such as buildings subject to occupancy by large numbers of persons, hotels, theaters, sports arenas, hospitals, and similar institutions. Storage batteries have been used for emergency power for short periods of time. Diesel or gas powered generator sets are generally installed for use when the normal service fails.

Emergency systems may provide power for such functions as: 1. Essential refrigeration; 2. Ventilation when essential to maintain life; 3. Operation of mechanical breathing apparatus; 4. Illumination and power for hospital operating rooms; 5. Fire pumps; 6. Industrial processes where current interruption would produce serious hazards; 7. Public address systems and similar functions.

DISCUSSION OF THE LESSON:

1. Discuss the emergency system needed for a hospital. How is the system approved for use? Who makes periodical tests and maintenance checks to insure proper operating conditions?

2. What current supply systems are available for installation where emergency lighting and power may be needed?

3. List some of the requirements for emergency circuits for lighting and power. Will independent wiring be required?

4. Discuss some of the controls for emergency lighting circuits. Who is responsible for overcurrent devices?

5. Explain what is meant by individual unit equipment.

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

MOBILE HOMES, RECREATION VEHICLES, AND PARKS

DESIRED RESULTS:

1. To acquaint the student with the N. E. Code requirements for electrical conductors and equipment installed within mobile homes, recreational vehicles, and parks.

2. To study the references related to the installation of electrical wiring, fixtures, equipment, and appurtenances in the above named places.

3. To learn the methods of connecting the mobile home service to the power supply.

INTRODUCTION:

Have the students read what the N. E. Code says about electrical installations in the above named areas. Review the need and the growing demands for electrical work in this area.

PRESENTING THE LESSON:

Suggested discussion questions:

1. Discuss the methods of connecting the mobile home service to the power supply.
2. What electrical installations are included in the mobile home at the factory.
3. Does each state set up its own laws concerning the wiring and inspection of mobile homes?
4. How does a prospective buyer know the type of wiring in a mobile home?
5. How is the number of branch circuits determined to a certain mobile home?
6. Define a recreational vehicle according to the N. E. Code.
7. Discuss some of the things to watch when making electrical installations in a recreational vehicle park.
8. How is this outdoor electrical equipment protected in wet locations?

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

SAMPLE HOUSE PLANS

DESIRED RESULTS:

To examine a sample house plan to determine the power load for appliances, cooling, heating, and lighting.

INTRODUCTION AND PRESENTING THE HOUSE PLANS:

The attached sample house plan should be examined, along with the help of information on the sheet, for the total power load. Also, using the three systems suggested for the heating requirements, and Notes 1, 2, 3, and 4, you should have one or two good sessions of blueprint reading.

It is suggested that the instructor make out a set of problems and questions to be used for the worksheet. Many questions may be local because of the types of equipment widely used in certain geographical or climate areas. Thus, it is suggested that these questions be prepared by the local instructor. The best way to teach Blueprint Reading is to give the student a variety of problems and questions concerning the equipment, heating area, heating load, sizes of the rooms, etc. Many problems in mathematics applied to electricity as used in a house can be prepared for this situation. Preparation and printing of the questions so that each student has a copy will be the best method of presenting the work.

APPLICATION:

Have the students examine the print using prepared questions to search out the answers.

CHECKING AND FOLLOW-UP:

Check the answers and discuss those that differ to arrive at a satisfactory understanding.

INFORMATION SHEET LESSON B-27

SAMPLE HOUSE PLAN

(BLUEPRINT READING)

The attached house plan has the following items of electrical equipment.

1.	Range - 230 V 1Ø	12 kw
2.	Disposer - 120 V	7.2 amps
3.	Dish Washer - 120 V	1350 W (13 amps)
4.	Clothes Washer - 120 V	9.8 amps
5.	Clothes Dryer - 230 V 1Ø	5.0 kw
6.	Electric Water Heater 230 V 1Ø	4.5 kw

The electric heating requirements; use one of the following systems:

ROOM NAME	SCHEME # 1 BASEBOARD	SCHEME # 2 CEILING CABLE	SCHEME # 3 CENTRAL ELECTRIC FURNACE
Living Room & Hall	3000 W	3000 W	230V 1 Ø
Dining & Kitchen	2000 W	2000 W	10 KW
Bedroom # 1	1250 W	1400 W	Duct Bank
Bedroom # 2	1250 W	1400 W	+ 1/3 HP 120V
Bedroom # 3	1000 W	1000 W	Fan
Bath # 1	500 W	400 W	
Bath # 2 (Half Bath)	500 W	200 W	

NOTES:

1. Optional cooling is by either of the following systems:

	Baseboard or Ceiling	Electric Furnace
Bedroom # 1	6.9 amp @ 230 V window unit	20,000 BTU Condenser @14.6 amps
Dining & Kitchen	9.8 amp @ 230 V window unit	230V + Fan at Furnace

NOTES (Continued)

2. It is interesting to note that the heating loads are different for the various systems. This is due to standard sizes of items and not from one system being more efficient or less expensive to operate than another.

   Baseboard Heaters - 8500 watts

   Ceiling Cables - 9400 watts

   Electric Furnace - 10000 watts

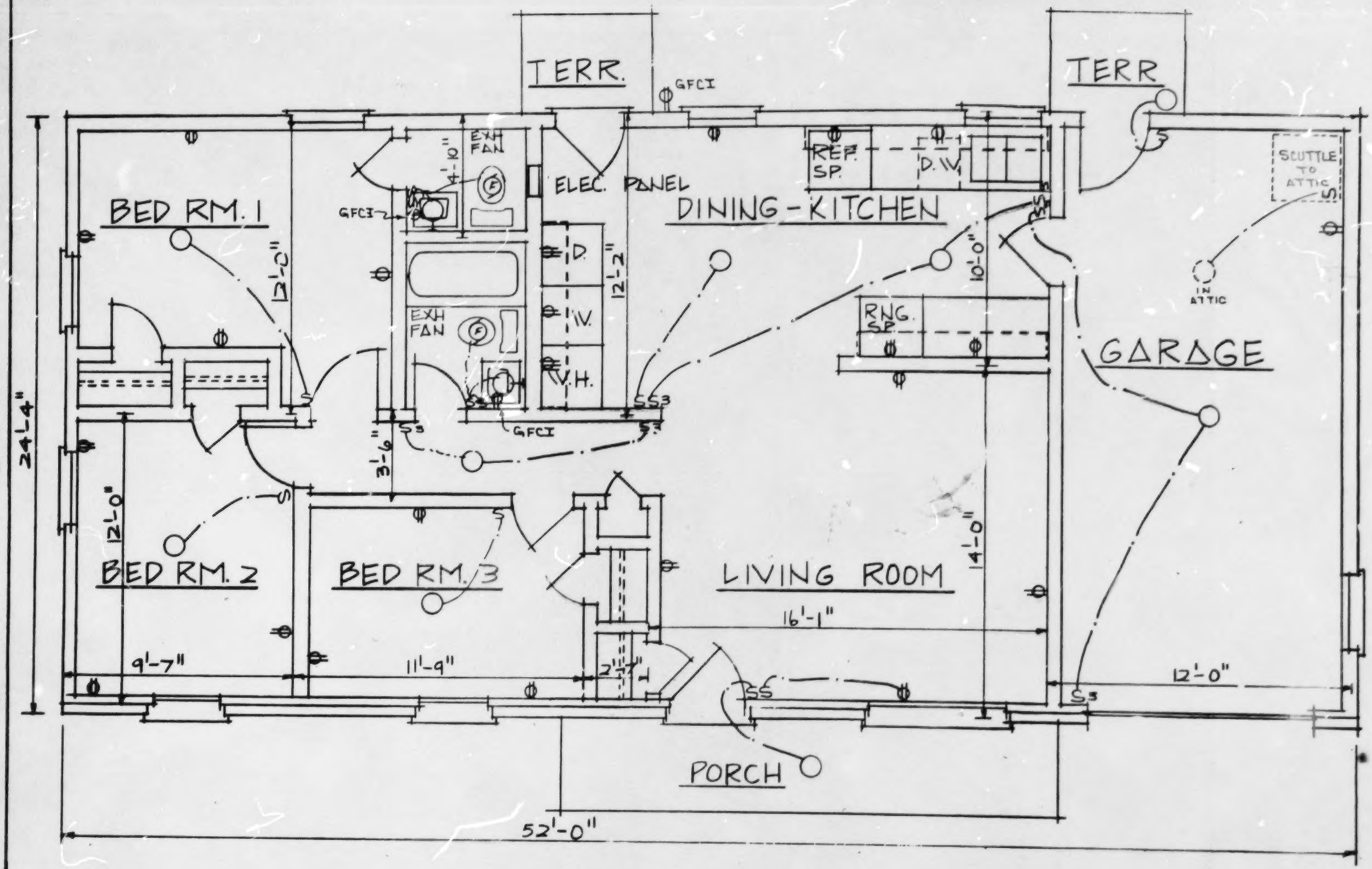
3. By the same reasons, the cooling systems differ:

   Central unit in furnace - 20,000 BTU

   Dining/Kitchen window unit - 15,000 BTU

   Bedroom # 1 window unit - 8,000 BTU

4. Both heating and cooling requirements assume construction typical for a home which qualifies for the "all-electric" rate from the serving utility, and a design temperature range for heating of 10° F outside and 70° F inside. Naturally, it would not be as much of a temperature differential for the cooling - 70° F inside to 95° F outside (estimated averages).



FLOOR PLAN

1978

0 4

120

STUDENT: GARY ROBBINS
STUDENT NO. 6248
326 PINEVIEW ST
ASHEBORO, N.C.

SHEET NO. 1 OF 1

FLOOR PLAN

GUILFORD TECHNICAL INSTITUTE, JAMESTOWN N.C.

ARCHITECTURAL TECHNOLOGY DEPARTMENT

121

OUTLET CIRCUITING

INTRODUCTION:

Calculation of building loads is based on Chapter 2 of the N. E. Code. The several optional methods of calculating a residential service make the task of providing correct answers an almost impossible task. Answers to the more standard circuits have been provided. The material outlined should be broken down into three or more class sessions.

PRESENTING THE LESSON:

The instructor should make the student aware of the various optional methods of calculating services and feeders and provide him with assistance and guidance in completing his assignment with the one method chosen/assigned. A class discussion of these different means of determining service sizes should provide a healthy group discussion. Not only should the electrical aspects of the problem be discussed, but the economic value of more circuits with less loading, customer satisfaction, and safety of individualized circuits for major items which require power should be weighed.

APPLICATION:

When the student has correctly figured the General Lighting loads and appliance outlets, and has understood the various methods of arriving at the correct answers, have him move on to the larger appliance circuits and one of the schemes for heating and air conditioning. The student should group certain loads where permissible, size the feeder required, and determine the correct overcurrent protective device needed for the feeder.

CHECKING AND FOLLOW-UP:

When all circuits have been developed, loads totaled, and feeders sized, have the student lay out the necessary circuits in the panel. Now, have the student size the service feeders, the grounding conductor, and the bonding required to completely and correctly meet the Code installation requirements.

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ASSIGNMENT REFERENCES

ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
		*Note #1 *Note #5	*Note #4	*Note #2	*Note #3	*Note #1	*Note #5
Alternating Current	C-1	384-390	1-42 thru 1-50		1-112 thru 1-121		Basic Math Pg. 493-500
Resistance in A.C. Circuits	C-2		3-31 thru 3-42		1-122 thru 1-32, 1-38		Basic Math Pg. 554-557
Inductance and Inductive Reactance	C-3	392-397 409-420	3-50 thru 3-64		1-44 thru 1-46		Basic Math Pg. 501-517
Capacitance and Capacitive Reactance	C-4	422-433	3-77 thru 3-111		1-47 thru 1-49, 1-129		Basic Math Pg. 534-552
Power Factor Correction	C-5	527-529 548-555	3-35		7-179		Basic Math Pg. 651, 669-679
Capacitors	C-6	422-424	3-93 thru 3-103	460	4-135 thru 4-139		Basic Math Pg. 534

*Note # 1: Page Numbers Listed
*Note # 2: Article Numbers Listed
*Note # 3: Division and Section Numbers Listed
*Note # 4: Chapter and Page Numbers Listed
*Note # 5: Basic Math References in left column are 2nd Edition; Basic Math Ref. in last column are 3rd Edition, 1972.

(Continued) ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
Power in A. C. Circuits	C-7		3-33 thru 3-38		1-134 thru 1-143, 1-152 thru 1-157		Basic Math Pg. 649-679
Hazardous Locations	C-8			500			Code Digest, Crouse-Hinds or Appleton
Class I Installations	C-9			501			Code Digest, Crouse-Hinds or Appleton
Class II Installations	C-10			502			Code Digest, Crouse-Hinds or Appleton
Class III Installations	C-11			503			Code Digest, Crouse-Hinds or Appleton
Commercial and Residential Garages	C-12			510 511			Code Digest, Crouse-Hinds or Appleton
Aircraft Hangars	C-13			513			Code Digest, Crouse-Hinds or Appleton

(Continued) ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N. E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
Gasoline Dispensing and Service Stations	C-14			514			Code Digest, Crouse-Hinds or Appleton
Bulk Storage Plants	C-15			515			Code Digest, Crouse-Hinds or Appleton
Finishing Processes	C-16			516			Code Digest, Crouse-Hinds or Appleton
Health Care Facilities	C-17			517			Code Digest, Crouse-Hinds or Appleton
Fundamentals of Motor Control	C-18			430	7-251 thru 7-277	1-9	GE Westinghouse Cutler Hammer Square D
Control of Motor Starting	C-19			430	7-251 thru 7-325	11-32	Allen Bradley Furnes
Control Components	C-20			430		33-70	Motor Control Booklets
Pilot Devices	C-21			430		71-87	Motor Control Booklets

(Continued) ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
Control Circuit Diagrams	C-22			430	7-443 thru 7-445	89-105	Motor Control Booklets
Development of Control Circuits	C-23			430		107-131	Motor Control Booklets
Material Take-Off	C-24						
Estimating	C-25						

ALTERNATING CURRENT

DESIRED RESULTS:

1. To acquaint the apprentice with the importance of alternating current.
2. To know the basic fundamentals of alternating current.
3. To study the terminology used in working with alternating current circuits.

INTRODUCTION:

Alternating currents have been referred to briefly in other lessons. As you know, most all of the electric power generated and transmitted in the United States is alternating current.

Five reasons are listed for using electrical energy as <u>alternating current</u> rather than direct current:

1. The A. C. generators have no commutators. Therefore, units having larger power ratings and resultant heavier current ratings can be used without the problem of brush arcing and heating.

2. Because alternators or A. C. generators have no commutators, they can generate at comparatively high voltages such as 11,000 to 13,000 volts.

3. Because alternating current can be transmitted economically over great distances, it is possible to generate electrical energy in large quantities in a single station and distribute it over a comparatively large territory.

4. By the use of the transformer, alternating current can be increased or decreased easily without much power loss.

5. For constant speed work, the A. C. squirrel-cage induction motor is less expensive than the direct current motor, both in cost and in maintenance.

PRESENTING THE LESSON:

I. The cycle:
Since we know that alternating current flows back and forth in a conductor at regular intervals, going first in one direction and then the other.

A. Develop the concept of the cycle using the four positions of a loop in an elementary gene ator.
B. Define cycle--Draw a waveform o sine wave and mark the points of maximum, average, and effective values. Have the students give definitions of cycle.

II. Discuss and define mechanical and electrical degrees
A. Compare two and four pole A. C. generators
Calculate the mechanical and electrical degrees in each generator per turn of rotor coil.
B. Arrive at the definitions.

III. Frequency
A. Compare the number of cycles generated per turn of rotor in two and four pole A. C. generators.
Calculate the number of cycles generated per second in each generator at a given speed.
B. Arrive at a definition of frequency.

IV. Phase
A. Definition of single phase
B. In-phase
1. Give definition
2. Illustrate VOLTAGE and CURRENT relationship using SINE WAVES. Draw waveform or SINE WAVE.
C. OUT OF PHASE - LAG
Definition
D. OUT OF PHASE - LEAD
Definition

APPLICATION:

The students should complete the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

RESISTANCE IN A. C. CIRCUITS

DESIRED RESULTS:

1. To acquaint the student with the effect of resistance only in A. C. circuits.
2. To understand the meaning of the term "power factor."

INTRODUCTION:

The effect of resistance in alternating current circuits which contain resistance only is the same as its effect in direct-current circuits. It causes a loss or drop in voltage, with a specified voltage, the greater the resistance, the smaller the current and vice versa. Remember that some materials have much less resistance than others. Pure resistance circuits are made up of electrical devices such as resistors, lamps, and heating elements which have negligible inductance or capacitance. When only such devices are used in an A. C. circuit, Ohm's Law, and the circuit rules for voltage, current, and power can be used in D. C. circuits.

Power in the A. C. circuit is determined in a similar manner as in a D. C. circuit by multiplying volts and amperes. When the power factor is other than unity, all A. C. voltage and current are given in effective values. Effective values are determined by considering the angle of lag or lead between voltage and current.

The power represented by the product of volts, amperes, and cosine is registered on a wattmeter or a watt-hour meter. It represents the power you pay for when furnished by the electric company.

PRESENTING THE LESSON:

1. Review the fundamental concepts of power

   a. A. C. resistance circuits

   b. Draw voltage and current wave

      Sine waves of voltage and currents are "in phase" whenever they are the same frequency and pass through zero simultaneously, both going in the same direction.

2. Determination of power

   a. Circuit having resistance only--measure the volt-amp and power supplied to: 134

(1) A reactor of negligible resistance

(2) A capacitor

b. Circuit having inductive or capacitive reactance

Measure the power supplied to a single-phase induction motor.

c. Present the general formula for single phase or A. C. power factor.

APPLICATION:

Have the students answer all questions; show all formulas used on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the papers.

INDUCTANCE AND INDUCTIVE REACTANCE

DESIRED RESULTS:

1. To acquaint the apprentice with the effects of inductance in an alternating current circuit.
2. To show the effects of inductive reactance in an A. C. circuit.

INTRODUCTION:

INDUCTANCE, which is treated in this assignment, is the electrical property that in an A. C. circuit imposes a counter or back voltage. When the current increases, inductance tries to hold it down and when the current decreases, inductance tries to hold it up. While you cannot see inductance, it is present in every electrical circuit an has the above effects on the circuit whenever the circuit current changes.

Inductance of a circuit is measured in a unit called "henrys." It is expressed by the symbol L. A circuit has an inductance of 1 henry when, if the current is changed at the rate of 1 ampere per second, 1 volt is induced into the circuit. You must understand inductance and inductive reactance in order to learn the basics of alternating current.

Inductive reactance is the opposition to current flow offered by the inductance of a current. As you know, inductance only affects current flow while the current is changing, since the current change generates an induced EMF, reactance is expressed in ohms as in resistance. In the formula inductive reactance is represented by the letters X_L.

Because an understanding of inductance and inductive reactance is fundamental to an understanding of alternating current, be sure that the students master this material including the use of formulas.

PRESENTING THE LESSON:

Remember that an alternating current is continuously changing so that the circuit inductance affects A. C. current flow at all times.

Because a coil of wire has more inductance than a straight length of the same wire, the coil is called an "inductor."

Resistors, coils, and capacitors may be connected in series in several combinations. A circuit which contains a resistor connected in series with a coil will be considered.

Resistors and coils offer opposition to alternating current. The voltage and current relationship in a resistor will be in phase while in a coil; the current lags the voltage drop across the coil by 90 degrees. The combined opposition is called impedance and is measured in ohms.

APPLICATION:

Have the students answer the questions and work the problems on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

CAPACITANCE AND CAPACITIVE REACTANCE

DESIRED RESULTS:

1. To help clarify the concept of capacitance by showing that when the voltage across an electric circuit changes, the circuit opposes this change.
2. To acquaint the student with the effects of capacitance reactance in an alternating current circuit.

INTRODUCTION:

A. Capacitance exists in an electric circuit because certain parts of the circuit are able to store electric charges. Capacitance is dependent on the area of the metal plates, the characteristics of the dielectric, and the distance between the plates. The effectiveness of a dielectric for use in a capacitor is described by a number called the "dielectric" constant. The number is based on the assumption that air has a dielectric of 1. Bakelite varies from 4.0 to 10.0, rubber compounds from 3.0 to 7.0, and paper from 2.0 to 2.6.

B. Capacitive reactance is the opposition to current flow offered by the capacitance of a circuit. It is measured in ohms, the same as resistance and inductive reactance. Capacitive reactance is designated by the symbol X_C. Alternating current continuously varies in value and polarity, therefore, the capacitor is continuously charging and discharging, resulting in a continuous circuit current flow and a finite value of capacitive reactance.

Inductive reactance and capacitive reactance have exactly opposite effects in a circuit. Inductive reactance opposes change of current in a circuit; capacitive reactance opposes change in voltage. In a series circuit the inductive reactance tends to neutralize the capacitive reactance.

PRESENTING THE LESSON:

A. What factors determine the reactance?

1. The size of the capacitor is one factor. The larger the capacitor, the greater the number of electrons that may be accumulated on its plates.
2. Increasing the distance between the plates decreases capacitance.

3. Changing the dielectric material changes the capacitance. Example, using mica as a dielectric increases the capacitance.

B. What is working voltage?

The working voltage is the largest voltage that may be placed across a capacitor before it breaks down. The working voltage in a parallel circuit is the working voltage of the weakest capacitor. The working voltage in series circuit is the sum of the working voltages of the series capacitor. See formulas--Basic Mathematics.

C. Show by using text Basic Electricity:

1. Charging and discharging currents of a capacitor.
2. How frequency affects the flow of A. C. current through a capacitor.
3. How capacitance values affect capacitive resistance.
4. In a pure capacitive circuit, the current leads the voltage.
5. Show the power wave of a circuit containing only capacitance.

DEMONSTRATIONS:

Use Basic Electricity

1. Charging a plate NEGATIVELY and POSITIVELY.
2. D. C. current flow stops when the capacitor becomes charged. Switch closed--capacitor charges, switch open--capacitor remains charged. Switch reversed--capacitor discharges and then charges with reversed polarity.
3. A. C. current in a capacitive circuit--charge and discharge currents cause a deflection on the A. C. ammeter.
4. To prove that capacitors appear to block D. C. but permit A. C. to pass.

REVIEW of capacitance in A. C. circuits by having the students explain the terms:

1. Capacitance
2. Capacitor
3. Capacitor charge
4. Capacitor discharge
5. Farad
6. Microfarad
7. Micromicrofarad
8. Dielectric

APPLICATION:

Have the students complete the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the papers.

POWER FACTOR CORRECTION

DESIRED RESULTS:

To acquaint the student with the method and importance of power factor correction.

INTRODUCTION:

Power is the rate of doing work. A watt is the unit of power or equal to the work done by the current of one ampere under the pressure of one volt. A wattmeter is not constructed with the basic meter movement. It used field coils with no permanent magnet to furnish the magnetic field. Since wattmeters work differently than other meters and are easily damaged if connected incorrectly, they must be operated properly.

Measurement of power factor can be done by using a power factor meter. The exterior of the single-phase power factor meter is identical to the wattmeter. While a source may produce volts and amperes, the power in watts may be small or zero. The ratio between the power in watts of a circuit and the volt-amperes of a circuit is called "power factor." In a pure resistive circuit the "power factor" is equal to power in watts divided by volt-amperes which equals one (1).

PRESENTING THE LESSON:

The ideal power transmission occurs when the current is in phase with the voltage or when the "power factor" is one (1). This can be accomplished by connecting a capacitor or a bank of capacitors across the line or in parallel with the inductive equipment.

The power-factor correction theory is not in the realm of apprentice work or the electrical maintenance department. It is an engineering problem and engineers should calculate the problems with the actual correction being made with capacitors or synchronous motors. The maintenance electrician should be familiar with the dangers in working with capacitors. A capacitor can maintain a charge sufficient to produce a fatal shock for a long time after it is disconnected from a charged line. A capacitor should be fully discharged before any maintenance work is done to it or around it.

APPLICATION:

The students will complete the questions and solve the problem on the assignment sheet.

CHECKING AND FOLLOW-UP:

The answers should be checked.

CAPACITORS

DESIRED RESULTS:

To acquaint the apprentice with construction, installation, use, markings, and protection of capacitors needed for industrial use.

INTRODUCTION:

Practically all electrical apparatus is composed of a combination of resistors or coils. Some industrial equipment such as capacitor motors, capacitor banks, and automatic switchgear use capacitors. Many kinds of capacitors are used in electricity and electronics. In order to choose the best type for a particular job, you should know how they are made and operate. You should be familiar with the symbols used to indicate certain special types of capacitors. Capacitors consist of two plates of electrical conducting material such as aluminum or tin, separated by an insulating material called the "dielectric," such as air, waxed paper, mica, glass, etc.

PRESENTING THE LESSON:

I. The meaning of capacitance
   A. Physical construction of a capacitor
      Two conductors with insulation between them
   B. Characteristics of a capacitor
      1. Will not pass current
      2. Will hold a current

APPLICATION:

Have the students complete the assignment questions.

CHECKING AND FOLLOW-UP:

Check the answers.

POWER IN AC CIRCUITS

DESIRED RESULTS:

1. To understand the meaning of the term "power factor."
2. To show the apprentice how power in an AC circuit is determined.

INTRODUCTION:

The power in a DC circuit is the product of volts and amperes. In an AC circuit, the voltage and current are seldom in phase. Incandescent lighting and heating are the exceptions. The apparent power or product of volts and amperes must be multiplied by a "power factor" to determine the true or real power.

Refer to AC Power Waveform, Basic Electricity.

For "in phase" voltage and current waves, all of the instantaneous powers are above the zero axis and the entire curve is above the zero axis. This is determined when two positive values are multiplied together, the result is positive, and whenever two negative values are multiplied together, the result is also positive.

PRESENTING THE LESSON:

I. Fundamental concepts of power
   - A. AC resistance circuits
   - B. AC inductive circuits
   - C. AC capacitive circuits

II. Determination of power
   - A. Circuit having resistance only
   - B. Circuit having inductive reactance or capacitive reactance
   - C. Circuit having a reactive load (capacitive or inductive)
   - D. General formula for "single phase" or AC power
   - E. Measurement of AC power

III. Power factor
   Concept, definition, and determination of power factor

APPLICATION:

The students will answer the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

HAZARDOUS LOCATIONS

DESIRED RESULTS:

1. To acquaint the student with the three classes of hazardous locations and the general type of wiring permitted in each place.
2. To be able to recognize a hazard and develop the ability to classify the hazard involved.

INTRODUCTION:

The assigned material for the next lessons deals with wiring in areas where there is danger of explosion or fire resulting from operation of the electrical installation. The CODE breaks down the various types of hazardous locations into three classes. Each of these three main divisions is subdivided into two smaller divisions. Various types of wiring and equipment have been specified for the different kinds of hazards. Class I deals with activities in which fire or explosion may result from gases or vapors. Class II deals with dusts and Class III is reserved for combustible fibers. There are two small division under each class. In the first section, the particular danger is imminent at any or all times during the normal course of operation. In the second section, the danger is not believed present under ideal conditions. It is likely to arise from a reasonably foreseeable accident.

PRESENTING THE LESSON:

First, the students should review the particular kinds of hazards covered by the three main divisions and the general type of wiring permitted in each location.

Second, the detailed requirements for each subclass should be carefully read.

The main benefits to be derived from this study are the ability to recognize a hazard and the ability to decide upon a rough classification of the hazard involved. After the wireman has accomplished this much, he should then study the more detailed rules concerning installation.

APPLICATION:

Have the students answer questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

I. Classification of Hazardous Atmospheres

Crouse-Hinds Code Digest

A. Definitions.

The definitions below are extracted from the 1975 National Electrical Code. These definitions are included to define and clarify the meaning and intent of Crouse-Hinds when terms such as "Explosion-proof" and "Dust-ignition-proof" are used in this publication.

"Explosion-proof Apparatus": Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and which operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby.

"Dust-ignition-proof," as used in this Article shall mean enclosed in a manner that will exclude ignitible amount of dusts or amounts that might affect performance or rating and that, where installed and protected in accordance with this Code, will not permit arcs, sparks, or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specified dust on or in the vicinity of the enclosure.

The National Electrical Code, which is widely used for classification purposes, divides atmospheric explosion hazards into three broad classes; they are summarized in Table 1. However, it must be understood that considerable skill and judgment must be applied when deciding to what degree an area contains hazardous concentrations of vapors, combustible dusts or easily ignitible fibers and flyings. Many factors, such as temperature, barometric pressure, humidity, ventilation, distance from the vapor source, etc. must be considered. When information on all factors concerned is properly evaluated, a consistent classification for the selection and location of electrical equipment can be developed. For further information on classification of areas see NFPA 70C.

The table shown in Appendix I lists many of the hazardous compounds used in business and industry, with their classification, flash points, ignition temperatures, explosive limits and vapor densities.

B. The National Electrical Code and Underwriters Laboratories.

The NEC is considered the definitive classification tool and contains explanatory data about ethyl ether (Class I, Group C) as used in hospital operating rooms, and for gasoline (Class I, Group D) as it may apply to storage areas, garages and gasoline stations. Specific installation practices have been set up for these heavier-than-air vapors. However, there is no such specific data for acetylene, whose vapor density is very near that of air. In the case of hydrogen used indoors, since its vapor density is so low, the most hazardous concentrations are likely to be in the upper portion of the room. A safe approach to electrical installations in Group A & B atmospheres is to install Class I equipment, or consult local inspectors for ruling on area classification.

Most states, municipalities and public service companies use the NEC as a guide for their inspectors.

Underwriters' Laboratories, Inc. (U/L) is a not for profit, independent organization testing for public safety. Its function is to determine whether or not devices and materials submitted to it are safe and can be used in the NEC category for which they were designed. To do this, it maintains extensive laboratory and testing facilities.

U/L's function does not include actual enforcement of the National Electrical Code. However, as previously indicated, inspection authorities use U/L's listing as criteria in carrying out their inspections of hazardous areas.

C. Class I Atmospheric Hazards.

Class I atmospheric hazards are divided not only into the four groups shown in the table, but also into two divisions.

Division 1 covers locations where flammable gases or vapors may exist under normal operating conditions, under frequent repair or maintenance operations, or where breakdown or faulty operation of process equipment might also cause simultaneous failure of electrical equipment.

Division 2 covers locations where flammable gases, vapors or volatile liquids are handled either in a closed system, or confined within suitable enclosures, or where hazardous concentrations are normally prevented by positive mechanical ventilation. Areas adjacent to Division 1 locations, into which gases might occasionally flow, would also belong in Division 2.

D. Class II Atmospheric Hazards.

Class II atmospheric hazards cover three groups of combustible dusts. Groups E and F are always Division 1. Group G may be either Division 1 or 2.

E. Class III Atmospheric Hazards.

Class III atmospheric hazards cover combustible fibers or flyings not likely to be in suspension in air in quantities sufficient to produce ignitable mixtures (Division 1.) and locations in which easily ignitable fibers are stored or handled (Division 2.).

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II. Prevention of External Ignition and Explosion

A. Sources of Ignition.

A source of energy is all that is needed to touch off an explosion when flammable gases or combustible dusts are mixed in the proper proportion with air.

One prime source of energy is electricity. Equipment such as switches, circuit breakers, motor starters, push button stations, or plugs and receptacles, can produce arcs or sparks in normal operation when contacts are opened and closed. This could easily cause ignition.

Next in degree of hazard are devices that produce heat, such as lighting fixtures and motors. Here, surface temperatures may exceed the safe limits of many flammable atmospheres. A loose lamp in a fixture socket presents a double hazard, as it may combine arcing with production of heat.

Finally, many parts of the electrical system can become potential sources of ignition in the event of insulation failure. This group would include wiring (particularly splices in the wiring), transformers, impedance coils, solenoids, and other low-temperature devices without make-or-break contacts.

Non-electrical hazards such as sparking metal can also easily cause ignition. A hammer, file or other tool that is dropped on masonry or on a ferrous surface is thus a hazard unless the tool is made of non-sparking material. For this reason, portable electrical equipment is usually made from aluminum or other material that will not produce sparks if the equipment is dropped.

Electrical safety, therefore, is of crucial importance. The electrical installation must prevent accidental ignition of flammable liquids, vapors and dusts released to the atmosphere. In addition, since much of this equipment is used outdoors or in corrosive atmospheres, the material and finish must be such that maintenance costs and shutdowns are minimized.

B. Combustion Principles.

Three basic conditions must be satisfied for a fire or explosion to occur:

1. A flammable liquid, vapor or combustible dust must be present in sufficient quantity.

2. The flammable liquid, vapor, or combustible dust must be mixed with air or oxygen in the proportions required to produce an explosive mixture.

3. A source of energy must be applied to the explosive mixture.

In applying these principles, the quantity of the flammable liquid or vapor that may be liberated and its physical characteristics must be recognized. For instance, lighter-than-air gases diffuse into the atmosphere so readily that, except in enclosed spaces, they may not produce hazardous mixtures in areas close to electrical installations.

Vapors from flammable liquids also have a natural tendency to disperse into the atmosphere, and rapidly become diluted to concentrations below the lower limit of the flammable (explosive) range, particularly when the air is moving.

The probability that the gas concentration may be above the upper limit of the explosive range does not afford any degree of safety, as the concentration must first pass through the explosive range to reach the upper limit.

C. Evaluation of Hazardous Areas.

Each area that contains gases or dusts that are considered hazardous must be carefully evaluated to make certain the correct electrical equipment is selected. Many hazardous atmospheres are Class I, Group D, or Class II, Group G. However, certain areas may involve other groups, particularly Class I, Groups B and C. Conformity with the National Electric Code requires use of fittings and enclosures approved for the specific hazardous gas or dust involved.

For Class I and Class II equipment see the Crouse-Hinds Construction Materials Catalog or your Crouse-Hinds field representative.

D. Intrinsically Safe Equipment.

The use of intrinsically safe equipment is primarily limited to process control instrumentation, since these electrical systems lend themselves to the low energy requirements. The NFPA 493-1969 provides information on the design, evaluation, and installation of this equipment. This document defines intrinsically safe equipment and wiring as:

Equipment and wiring that are incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration.

Underwriters Laboratories, Inc. & Factory Mutual list several devices in this category. The equipment and its associated wiring must be installed so they are positively separated from the non-intrinsically safe circuits. Induced voltages could defeat the concept of intrinsically safe circuits.

Crouse-Hinds Code Digest

II. Prevention of External Ignition and Explosion

E. Enclosures for Class I, Divisions 1 and 2 Conditions.

In both Division 1 and 2 of Class I locations, conventional relays, contactors and switches incorporating metal-to-metal contacts must be enclosed in explosion-proof housings.

By definition, enclosure for these locations must prevent the ignition of an explosive gas or vapor that may surround it. In other words, an explosion inside the enclosure must be prevented from starting a larger explosion on the outside.

Adequate strength is one requirement for such an enclosure. In most hazardous location designs for Class I, Divisions 1 & 2, a safety factor of 4 is used; i.e., the item must withstand a hydrostatic test of four times the maximum pressure from an explosion within the enclosure.

In addition to being strong, the enclosure must be "flame-tight." This term does not imply that the enclosure is hermetically sealed but rather that the joints or flanges are held within narrow U/L tolerances. These carefully machined joints cool the hot gases resulting from an internal explosion so that by the time they reach the outside hazardous atmosphere, they are too cool to effect ignition.

The strains and stresses caused by internal explosive pressures are illustrated in fig. 1. Dotted lines indicate shape that a rectangular enclosure strives to attain under these conditions. Openings in an enclosure for these applications can be threaded-joint type (fig. 2) or ground-joint type (fig. 3).

Fig. 1. Explosive forces.

Fig. 2. Threaded joint opening.

Fig. 3. Ground joint opening.

F. Purging/Pressurization Systems.

Purging/Pressurization Systems permit the safe operation of electrical equipment under conditions of hazard for which approved equipment may not be commercially available.

For instance, most switchgear units and many large-size motors do not come in designs approved for Class I, Groups A and B.

Whether cast enclosures for hazardous locations or sheet metal enclosures with pressurization should be used is mainly a question of economics, if both types are available. As a typical example, if an installation had many electronic instruments that could be enclosed in a single sheet-metal enclosure, the installation would lend itself to the Purging/Pressurization System. However, if the instruments, due to their nature, had to be installed in separate enclosures, then the cast, hazardous location housing would almost invariably prove more economical.

Pressurized enclosures require:

- A source of clean air or inert gas.
- A compressor to maintain the required pressure on the system.
- Pressure control valves, to prevent the power from being applied before the cases have been purged, and to de-energize the system should pressure fall below a safe value.

In addition, door-interlock switches are required to prevent access to the equipment while the circuits are energized. It can readily be seen that all of these accessories can add up to a considerable expenditure.

For a detailed description of Purging/Pressurizing Systems see NFPA Bulletin 496 titled "Purged and Pressurized Enclosures for Electrical Equipment 1974". Or refer to the Canadian Electrical Code article entitled "A Suggested Method for Air Pressurizing Electrical Wiring Systems and Equipment in Class I Hazardous Locations, Appendix H, Rule 18-026, CEC Part I".

Crouse-Hinds Code Digest

I. Classification of Hazardous Atmospheres

Table I **Summary of Hazardous Atmospheres** **(Based on National Electric Code and U/L)**

Class	Division	Group	Typical atmosphere/Ignition temps.	Devices covered	Temperature measured	Limiting value
I Gases, vapors	1 Normally hazardous	A	acetylene (305C, 581F)	All electrical devices and wiring	Maximum external temperature in 40C ambient	See Sect. 500-2 of NEC
		B	butadiene[1] (420C, 788F) ethylene oxide[2] (429C, 804F) hydrogen (400C, 752F) manufactured gases containing more than 30% hydrogen (by volume) propylene oxide[2] (449C, 840F)			
		C	acetaldehyde (175C, 347F) cyclopropane (500C, 932F) diethyl ether (160C, 320F) ethylene (490C, 914F) unsymmetrical dimethyl hydrazine (UDMH 1, 1-dimethyl hydrazine) (249C, 480F)			
		D	acetone (465C, 869F) acrylonitrile (481C, 898F) ammonia[3] (651C, 1204F) benzene (560C, 1040F) butane (405C, 761F) 1-butanol (butyl alcohol) (365C, 689F) 2-butanol (secondary butyl alcohol) (405C, 761F) n-butyl acetate (425C, 797F) isobutyl acetate (421C, 790F) ethane (515C, 959F) ethanol (ethyl alcohol) (356C, 689F) ethyl acetate (427C, 800F) ethylene dichloride (413C, 775F) gasoline (56-60 octane: 280C, 536F) (100 octane: 456C, 853F) heptanes (280C, 536F) hexanes (225C, 437F) isoprene (220C, 428F) methane (natural gas) (482 to 632C, 900 to 1170F) methanol (methyl alcohol) (385C, 725F) 3-methyl-1-butanol (isoamyl alcohol) (350C, 662F) methyl ethyl ketone (516C, 960F) methyl isobutyl ketone (460C, 860F) 2-methyl-1-propanol (isobutyl alcohol) (427C, 800F) 2-methyl-2-propanol (tertiary butyl alcohol) (480C, 896F) petroleum naphtha[4] (288C, 550F) octanes (220C, 428F) pentanes (260C, 500F) 1-pentanol (amyl alcohol) (300C, 572F) propane (450C, 842F) 1-propanol (propyl alcohol) (440C, 824F) 2-propanol (isopropyl alcohol) (399C, 750F) propylene (460C, 860F) styrene (490C, 914F) toluene (480C, 896F) vinyl acetate (427C, 800F) vinyl chloride (472C, 882F) xylenes (530C, 986F)			

Table I cont'd. **Summary of Hazardous Atmospheres† (Based on National Electrical Code)**

Class	Division	Group	Typical atmosphere/ignition temps.	Devices covered	Temperature measured	Limiting value
	2 Not normally hazardous	A	Same as Division 1	Lamps, resistors, coils, etc., other than arcing devices. (see Div. 1)	Max. internal or external temp. not to exceed the ignition temperature in degrees Celsius (°C) of the gas or vapor involved	See Sect. 500-2
		B	Same as Division 1			
		C	Same as Division 1			
		D	Same as Division 1 (Not normally hazardous means that the gases aren't normally present.)			
II Combustible dusts	1 Normally hazardous	E	Metal dust, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics.	Devices not subject to overloads (switches, meters)	Max. external temp. in 40C ambient with a dust blanket	No overload: E-200C (392F) F-200C (392F) G-165C (329F)
		F	Carbon black, coal, coke dust with more than 8% volatile material.	Devices subject to overload (motors, transformers)		Possible overload: E, F, G—120C (248F) but not to exceed no-overload values at overload
		G	Flour, starch, grain dusts.			
	2 Not normally hazardous	G	Same as Division 1	Lighting fixtures	Max. external temp. under conditions of use	Group: G—165C(329F)
III Easily ignitible fibers and flyings	1, 2			Lighting fixtures	Max. external temp. under conditions of use	165C (329F)

[1] Group D equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit ½-inch size or larger.

[2] Group C equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit ½-inch size or larger.

[3] For Classification of areas involving ammonia atmosphere, see Safety Code for Mechanical Refrigeration (ANSI B9.1-1971) and Safety Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1-1972).

[4] A saturated hydrocarbon mixture boiling in the range 20—135°C (68—275°F). Also known by the synonyms benzine, ligroin, petroleum ether or naptha.

† For a complete list noting properties of flammable liquids, gases and solids refer to NFPA No. 325M-1969.

Appendix I

Substances Used in Business and Industry

Crouse-Hinds Code Digest

Class I Group	Substance	Flash Point Degrees F	Flash Point Degrees C	Ignition Temp. Degrees F	Ignition Temp. Degrees C	Explosive Limits Per cent by Volume Lower	Explosive Limits Per cent by Volume Upper	Vapor Density (Air Equals 1.0)
C	acetaldehyde	−36	−38	347	175	4	60	1.5
D	acetone	0	−17	869	465	2.6	12.8	2.0
A	acetylene	gas	gas	581	305	2.5	100	0.9
D	acrylonitrile	32	0	898	481	3	17	1.8
D	ammonia	gas	gas	1204	651	16	25	0.6
D	benzene	12	−11	1040	560	1.3	7.1	2.8
B	butadiene	gas	gas	788	420	2	12	1.9
D	butane	gas	gas	761	405	1.9	8.5	2.0
D	1-butanol (butyl alcohol)	84	29	689	365	1.4	11.2	2.6
D	2-butanol (secondary butyl alcohol)	75	24	761	405	1.7 @ 212°F, 100°C	9.8 @ 212°F, 100°C	2.6
D	n-butyl acetate	72	22	797	425	1.7	7.6	4.0
C	cyclopropane	gas	gas	932	500	2.4	10.4	1.5
C	diethyl ether	−49	−45	320	160	1.9	36	2.6
D	ethane	gas	gas	959	515	3	12.5	1.0
D	ethanol (ethyl alcohol)	55	13	689	365	3.3	19	1.6
D	ethyl acetate	24	−4	800	427	2.2	11	3.0
C	ethylene	gas	gas	914	490	2.7	36	1.0
D	ethylene dichloride	56	13	775	413	6.2	16	3.4
B	ethylene oxide	<0	<−17	804	429	3.6	100	1.5
D	gasoline:							
	56-60 octane	−45	−48	536	280	1.4	7.6	3-4
	100 octane	−36	−38	853	456	1.4	7.4	3-4
D	heptanes	25-<32	−4 to 0	419-536	215-280	1.05	6.7	3.5
D	hexanes	−7	−22	437	225	1.1	7.5	3.0
B	hydrogen	gas	gas	752	400	4.0	75	0.1
D	isobutyl acetate	64	18	790	421	2.4	10.5	4.0
D	isoprene	−65	−54	428	220	2	9	2.4
D	methane (marsh gas)	gas	gas	1004	538	5	15	0.6
D	methanol (methyl alcohol)	52	11	725	385	6.7	36	1.1
D	3-methyl-1-butanol (isamyl alcohol)	109	43	662	350	1.2	9	3.0
D	methyl ethyl ketone	21	−6	960	516	1.8	10	2.5
D	methyl isobutyl ketone	73	23	860	460	1.4	7.5	3.5
D	2-methyl-1-propanol (isobutyl alcohol)	82	28	800	427	1.2 @ 212°F, 100°C	10.9 @ 212°F, 100°C	2.6
D	2-methyl-2-propanol (tertiary butyl alcohol)	52	11	896	480	2.4	8	2.6
D	octanes	56	13	428	220	1.0	6.5	3.9
D	pentanes	<−40	<−40	500	260	1.5	7.8	2.5
D	1-pentanol (amyl alcohol)	91	33	572	300	1.2	10 @ 212°F, 100°C	3.0
D	petroleum naphtha	<0	<−17	550	288	1.1	5.9	2.5
D	propane	gas	gas	842	450	2.2	9.5	1.6
D	1-propanol (propyl alcohol)	77	25	824	440	2.1	13.5	2.1
D	2-propanol (isopropyl alcohol)	53	12	750	399	2	12	2.1
D	propylene	gas	gas	860	460	2	11.1	1.5
B	propylene oxide	−35	−37			2.8	37	2.0
D	styrene	90	32	840	449	1.1	6.1	3.6
D	toluene	40	4	914	490	1.2	7.1	3.1
C	unsymmetrical dimethyl hydrazine (UDMH 1, 1-dimethyl hydrazine)	5	−15	896 480	480 249	2	95	2.0
D	vinyl acetate	18	−8	800	427	2.6	13.4	3.0
D	vinyl chloride	gas	gas	882	472	3.6	33	2.2
D	xylenes	81	27	986	530	1.1	7	3.7

513-6. Stanchions, Rostrums, and Docks.

(a) IN HAZARDOUS LOCATION. Electric wiring, outlets, and equipment (including lamps) on or attached to stanchions, rostrums, or docks that are located or likely to be located in a hazardous location as defined in Section 513-2(c) shall comply with the requirements for Class I, Division 2 locations.

(b) NOT IN HAZARDOUS LOCATION. Where stanchions, rostrums, or docks are not located or likely to be located in a hazardous location as defined in Section 513-2(c), wiring and equipment shall comply with Sections 513-4 and 513-5, except that such wiring and equipment not more than 18 inches above the floor in any position shall comply with (a) above. Receptacles and attachment plugs shall be locking type that will not readily disconnect.

(c) MOBILE TYPE. Mobile stanchions with electric equipment complying with (b) above shall carry at least one permanently affixed warning sign to read: "WARNING —KEEP 5 FEET CLEAR OF AIRCRAFT ENGINES AND FUEL TANK AREAS."

513-7. Sealing.

Approved seals shall be provided in accordance with Section 501-5. Sealing requirements specified in Sections 501-5(a)(4) and 501-5(b)(2) shall apply to horizontal as well as to vertical boundaries of the defined hazardous locations. Raceways embedded in a masonry floor or buried beneath a floor shall be considered to be within the hazardous location above the floor where any connections or extensions lead into or through such location.

513-8. Aircraft [illegible] Systems.

Aircraft electrical systems shall be de-energized when the aircraft is stored in a hangar, and, whenever possible, while the aircraft is undergoing maintenance.

513-9. Aircraft Battery— Charging and Equipment.

Aircraft batteries shall not be charged when installed in an aircraft located inside or partially inside a hangar.

Battery chargers and their control equipment shall not be located or operated within any of the hazardous areas defined in Section 513-2, and shall preferably be located in a separate building or in an area such as described in Section 513-2(d). Mobile chargers shall carry at least one permanently affixed warning sign to read: "WARNING—KEEP 5 FEET CLEAR OF AIRCRAFT ENGINES AND FUEL TANK AREAS." Tables, racks, trays, and wiring shall not be located within a hazardous location, and, in addition, shall comply with Article 480.

513-10. External Power Sources for Energizing Aircraft.

(a) NOT LESS THAN 18 INCHES ABOVE FLOOR. Aircraft energizers shall be so designed and mounted that all electric equipment and fixed wiring will be at least 18 inches above floor level and shall not be operated in a hazardous location as defined in Section 513-2(c).

(b) MARKING FOR MOBILE UNITS. Mobile energizers shall carry at least one permanently affixed warning sign to read: "WARNING—KEEP 5 FEET CLEAR OF AIRCRAFT ENGINES AND FUEL TANK AREAS."

(c) CORDS. Flexible cords for aircraft energizers and ground support equipment shall be approved for the type of service and extra-hard usage and shall include an equipment grounding conductor.

513-11. Mobile Servicing Equipment with Electric Components.

(a) GENERAL. Mobile servicing equipment (such as vacuum cleaners, air compressors, air movers, etc.) having electric wiring and equipment not suitable for Class I, Division 2 locations shall be so designed and mounted that all such fixed wiring and equipment will be at least 18 inches above the floor. Such mobile equipment shall not be operated within the hazardous location defined in Section 513-2(c) and shall carry at least one permanently affixed warning sign to read: "WARNING—KEEP 5 FEET CLEAR OF AIRCRAFT ENGINES AND FUEL TANK AREAS."

(b) CORDS AND CONNECTORS. Flexible cords for mobile equipment shall be suitable for the type of service and approved for extra-hard usage, and shall include an equipment grounding conductor. Attachment plugs and receptacles shall be approved for the location in which they are installed, and shall provide for connection of the grounding conductor to the raceway system.

(c) RESTRICTED USE. Equipment not suitable for Class I, Division 2 locations shall not be operated in locations where maintenance operations likely to release flammable liquids or vapors are in progress.

513-12. Grounding.

All metal raceways and all noncurrent-carrying metal portions of fixed or portable equipment, regardless of voltage, shall be grounded as provided in Article 250.

Recommended installation for aircraft hangars

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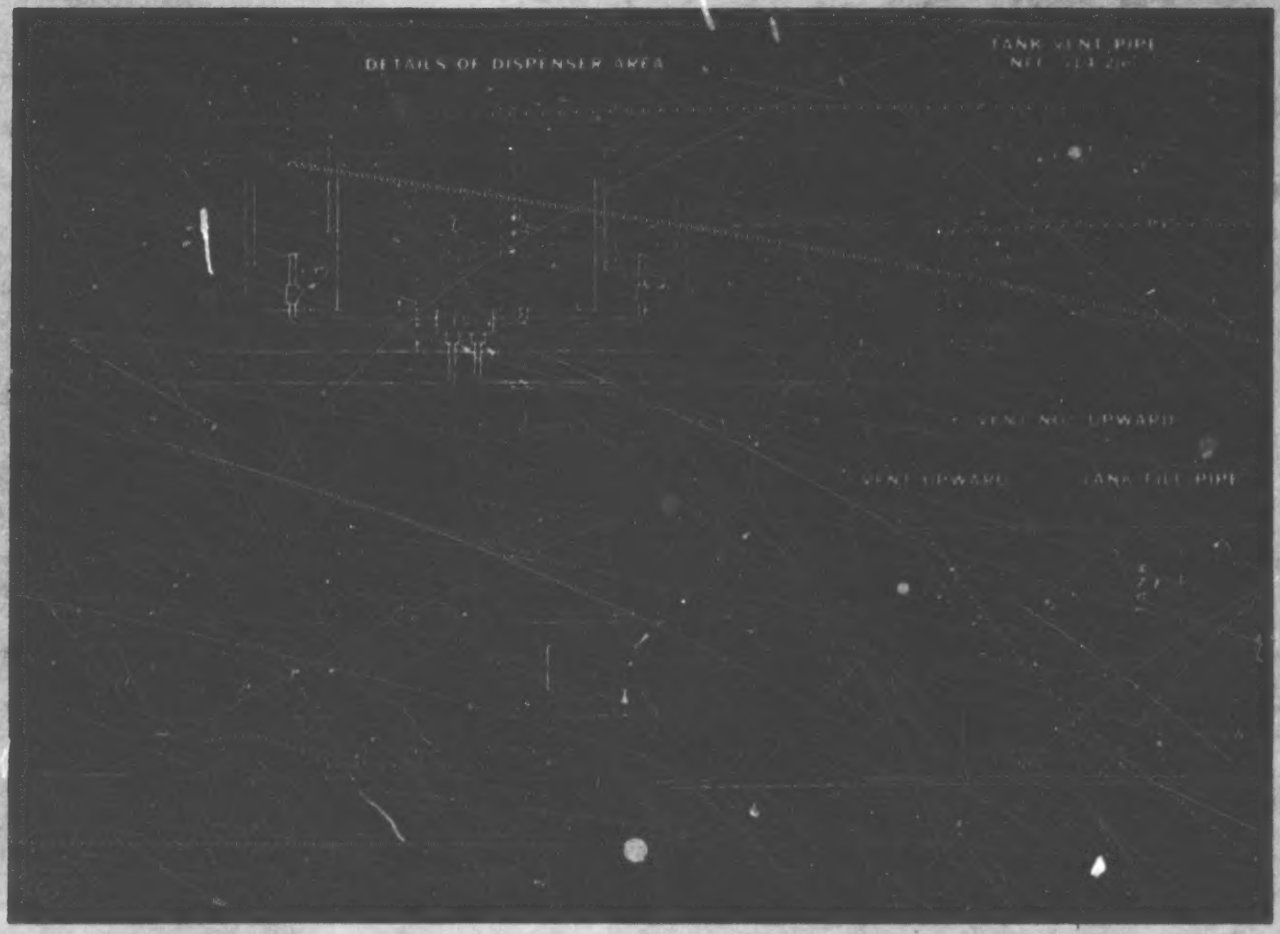
Article 514
Gasoline Dispensing and Service Stations

Crouse-Hinds Code Digest

◀ Pole standard within 20 ft. horizontally from any dispensing island or pump, or from any tank fill-pipe or tank vent-pipe is Class I, Division 2. See 514-2(b).

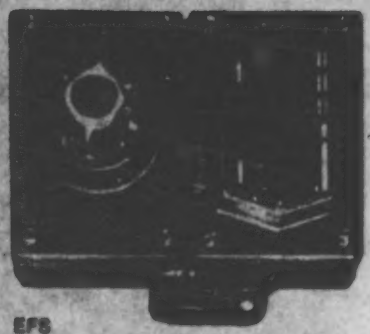
▶ A building less than 20 ft. from any island, pump, tank fill-pipe, or tank vent-pipe is a Class I, Division 2 location up to 18 inches above grade.

Note
If a building is over 20 feet from any island, pump, tank fill-pipe, or tank vent-pipe it is not a hazardous location. But in either case seals must be placed in all underground conduits to prevent explosions in conduits from reaching panelboard. See 514-6 (a) and (b).



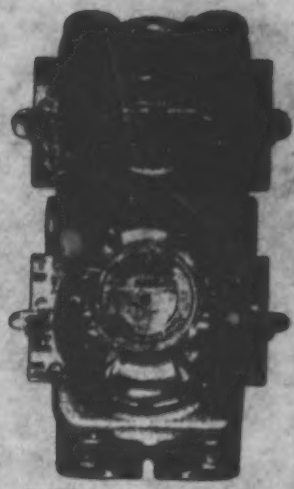
Article 515
Bulk-Storage Plants

Crouse-Hinds Code Digest

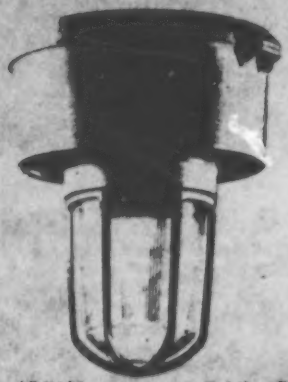


EFS
Push button station and pilot light

GUSC Enclosure with switch circuit breaker or manual starter



GUSC
Combination manual starter and circuit breaker enclosure



VMV Mercury vapor lighting fixture

VXHT Incandescent lighting fixture

Note: The VMV and VDC fixtures are suitable for Class I, Div. 2. All other enclosures on these two pages are suitable for use in Class I, Division 1 locations in bulk storage plants.

(4) For spraying operations confined to an enclosed spray booth, the space within 3 feet in all directions from any openings in the spray booth.

(5) All space within the room but beyond the limits for Class I, Division 1 as defined in Section 516-2(a) for dip tanks and drain boards, and for other hazardous operations.

(c) ADJACENT LOCATIONS. Adjacent locations that are cut off from the defined hazardous locations by tight partitions without communicating openings, and within which hazardous vapors are not likely to be released, shall be classified as nonhazardous unless the authority having jurisdiction judges otherwise.

(d) NONHAZARDOUS LOCATIONS. Locations utilizing drying, curing, or fusion apparatus and provided with positive mechanical ventilation adequate to prevent formation of flammable concentrations of vapors, and provided with effective interlocks to de-energize all electric equipment (other than equipment approved for Class I locations) in case the ventilating equipment is inoperative, may be classified as nonhazardous where the authority having jurisdiction so judges.

For further information regarding safeguards, see Ovens and Furnaces, Design, Location and Equipment (NFPA No. 86A-1973).

516-3. Wiring and Equipment in Hazardous Locations.

(a) WIRING AND EQUIPMENT—VAPORS. All electric wiring and equipment within the hazardous location (containing vapor only—not residues) defined in Section 516-2 shall comply with the applicable provisions of Article 501.

(b) WIRING AND EQUIPMENT—VAPORS AND RESIDUES. Unless approved for both readily ignitible deposits and the flammable vapor location, no electric equipment shall be installed or used where it may be subject to hazardous accumulations of readily ignitible deposits or residues, as the susceptibility to spontaneous heating and ignition of some residues may be greatly increased at temperatures above normal. Type MI cable and wiring in threaded rigid metal conduit may be installed in such locations, if the explosion-proof boxes or fittings contain no taps, splices, or terminal connections that may possibly become loose in service and thereby cause abnormal temperatures on external surfaces of boxes or fittings.

(c) ILLUMINATION. Illumination of readily ignitible areas through panels of glass or other transparent or translucent material shall be permitted only if it complies with the following: (1) fixed lighting units are used as the source of illumination; (2) the panel effectively isolates the hazardous location from the area in which the lighting unit is located; (3) the lighting unit is approved for its specific location; (4) the panel is of a material or is so protected that breakage will be unlikely; and (5) the arrangement is such that normal accumulations of hazardous residue on the surface of the panel will not be raised to a dangerous temperature by radiation or conduction from the source of illumination.

(d) PORTABLE EQUIPMENT. Portable electric lamps or other utilization equipment shall not be used within a hazardous location during operation of the finishing process. When such lamps or utilization equipment are used during cleaning or repairing operations, they shall be of a type approved for Class I, Group D, Division 1 locations, and all exposed metal parts shall be effectively grounded.

(e) ELECTROSTATIC EQUIPMENT. Electrostatic spraying or detearing equipment shall be installed and used only as provided in Section 516-4.

For further information, see NFPA Standard for Spray Application Using Flammable and Combustible Materials (NFPA No. 33-1973).

516-4. Fixed Electrostatic Equipment.

This Section shall apply to any equipment using electrostatically charged elements for the atomization, charging, and/or

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Appendix V

Diagram for Class I, Div. 1 Lighting Installation

Crouse-Hinds Code Digest

Key to Numerals

1 Sealing fitting. EYS for horizontal or vertical.
2 Sealing fitting. EZS for vertical or horizontal conduits.
3 Circuit breaker. Type EPC.
4 Panelboard. EDP. Branch circuits are factory sealed. No seals required in mains or branches unless 2" or over in size.
5 Junction box. Series GUA, GUB, GUJ, have threaded covers. Series CPS has ground flat surface covers.
6 Fixture hanger. EFHC, GUAC or EFH.
7 Lighting fixture. EV series.
8 Flexible fixture support. ECGH or EFH.
9 Fluorescent fixture. EVF.
10 Float switch. EMS.
11 Signal. ETH horns and sirens. ESR Bells.
12 Vieularm EKP.
13 Plug receptacle. CES-delayed action.
14 Plug receptacle. FSQ. Interlocked with switch.
15 Breather. ECD.
16 Drain. ECD.
17 Union. UNY.
18 Switch. Series EFS.
19 Manual line starter. FLF.
20 Manual line starter. GUSC.
21 Motors, explosion-proof.

National Electrical Code References

a Par. 501-5a-4. Seal required where conduit passes from hazardous to non-hazardous area.
b Par. 501-5a-1. Seals required within 18 inches of all arcing devices.
c Sec. 384-16. Circuit breaker or rating not greater than rating of panelboard required if supply conductors have overcurrent protection over 200 amperes.
d Par. 501-5a-2. Seals required if conduit is 2 inches or larger.
e Par. 501-4a. All arcing devices must be explosion-proof.
f Par. 501-4a. All boxes must be explosion-proof and threaded for rigid conduit.
g Par. 501-9a-4. All boxes and fittings for support of lighting fixtures must be approved for the purpose.
h Par. 501-9a-1. All lighting fixtures fixed or portable must be explosion-proof.
i Par. 501-9a-3. Pendent fixture stems must be threaded rigid conduit or approved flexible connector. Rigid stems if over 12 inches must have flexible connector, or must be braced.
j Sec. 501-14a. All signal circuits irrespective of voltage must be approved for Class I location.
k Sec. 501-12. Receptacles and plugs must be explosion-proof and provide grounding connections for portable equipment.
l Par. 501-5f. Breathers and drains needed in all humid locations.
m Par. 501-4a. All joints and fittings must be explosion-proof.
n Par. 501-8a. Motor must be suitable for Class I.
p Art. 430. Motor overcurrent protection.

Appendix VI

Diagram for Class I, Div. 1 Power Installation

Key to Numerals

1 Sealing fitting. EYS for horizontal or vertical.

2 Sealing fitting. EZS for vertical or horizontal conduits.

3 Circuit breaker EPC.

4 Junction box series GUA, GUE and GUJ have threaded covers. Series CPS and Type LBH have ground flat surface covers.

5 Circuit breaker FLB.

6 Manual line starter FLF.

7 Magnetic line starter GUB.

8 Combination circuit breaker and line starter EPC.

9 Switch or motor starter. Series EFS or GUSC.

10 Push button station. Series EFS or OFC.

11 Breather. ECD.

12 Drain. ECD.

13 Union. UNF.

14 Union. UNY.

15 Flexible coupling. ECH.

16 Plug receptacle. CES. Factory sealed.

17 Motor for hazardous location.

National Electrical Code References

a Par. 501-5a-3. Seals required where conduits pass from hazardous to non-hazardous area.

b Par. 501-5a-1. Seals required within 18 inches of all arcing devices.

c Art. 430 should be studied for detailed requirements for conductors, motor feeders, motor feeder and motor branch circuit protection, motor overcurrent protection, motor controllers and motor disconnecting means.

d Par. 501-5a-2. Seals required if conduit is 2 inches or larger in size.

e Par. 501-4a. All boxes must be explosion-proof and threaded for rigid conduit.

f Par. 501-6a. Push button stations must be explosion-proof.

g Par. 501-5d. Breathers and drains needed in all humid locations.

h Par. 501-4a. All joints and fittings must be explosion-proof

i Par. 501-4a. Flexible connections must be explosion-proof.

j Sec. 501-12. Receptacles and plugs must be explosion-proof, and provide grounding connections for portable devices.

Appendix VI

Diagram for Class I, Div. 2 Power and Lighting Installation

Crouse-Hinds Code Digest

Key to Numerals

1 Sealing fitting. EYS for horizontal or vertical.
2 Sealing fitting. EZS for vertical or horizontal conduits.
3 Circuit breaker. Type EPC.
4 Panelboard. D2PB, N2PB. Branch circuits are factory sealed.
5 Junction box or conduit fitting. NJB, obround.
6 Fixture hanger. AHG, GS, UNJ.
7 Lighting fixture. VMV (Relamp Champ).
8 Flexible fixture support.
9 Handlamp. EVH.
10 Float switch. EMS.
11 Signal. ETH horns and sirens. ESR Bells.
12 Visualarm EKP.
13 Plug receptacle. CES-delayed action.
14 Plug receptacle. FSQ. Interlocked with switch.
15 Breather. ECD.
16 Drain. ECD.
17 Union. UNY.
18 Switch. Series EFS.
19 Manual line starter. FLF.
20 Manual line starter. GUSC.
21 Motors. Suitable for Class I locations.

National Electrical Code References

a Par. 501-5b-2. Seal required where conduit passes from hazardous to non-hazardous area.
b Par. 501-5b-1. Seals required within 18 inches of all arcing devices.
c Sec. 384-16. Circuit breaker or rating not greater than rating of panelboard required if supply conductors have overcurrent protection over 200 amperes.
d Par. 501-9b-2. All fixed lighting fixtures shall be enclosed and gasketed and not exceed ignition temperature of the gas.
e Par. 501-6b1. All arcing devices must be explosion-proof.
f Par. 501-4b. All boxes must be threaded for rigid conduit.
g Par. 501-9b-4. All boxes and fittings for support of lighting fixtures must be approved for the purpose.
h Par. 501-9b-1. All portable lighting fixtures must be explosion-proof.
i Par. 501-9b-3. Pendent fixture stems must be threaded rigid conduit or approved flexible connector. Rigid stems if over 12 inches must have flexible connector, or must be braced.
j Sec. 501-14-b. All signalling equipment must be approved for Class I location.
k Sec. 501-12. Receptacles and plugs must be explosion-proof and provide grounding connections for portable equipment.
l Par. 501-5f. Breathers and drains needed in all humid locations.
m Par. 501-4b. All joints and fittings are not required to be explosion-proof.
n Par. 501-8b. Motor shall be suitable for Div. 2.
p Art. 430. Motor overcurrent protection.

Appendix VII

Diagram for Class II Lighting Installation

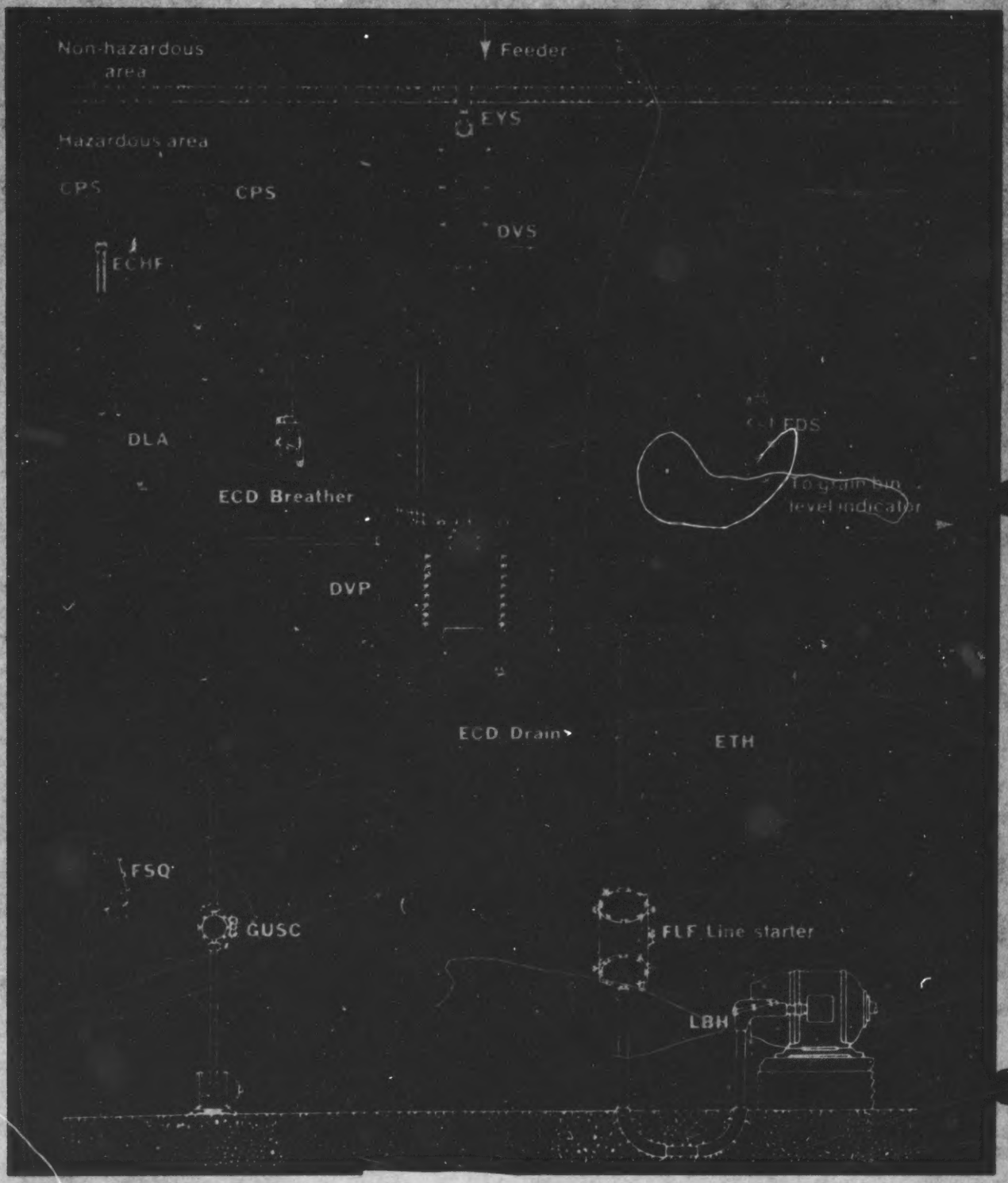
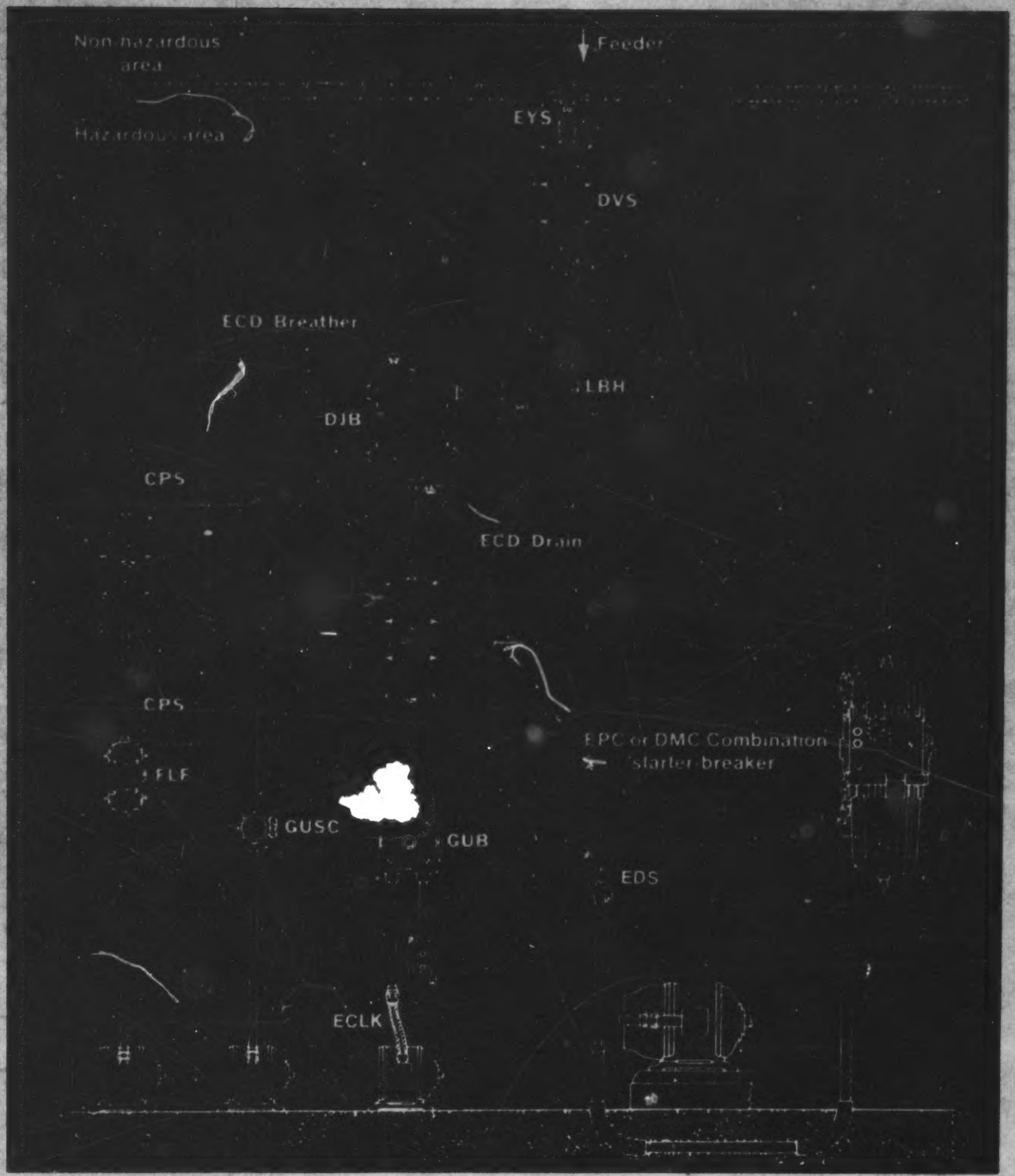


Diagram for Class II Power Installation



Appendix IX

"Quick-Selector" Electrical Equipment for Hazardous Locations

Note: Not all types listed are suitable for use in all four groups of Class I hazardous locations. Consult catalog listing pages for applicable classes and groups.	Class I Div. 1	Class I Div. 2	Class II Div. 1		Class II Div. 2 (Group G only)	Class III Div. 1	Class III Div. 2
			Group E & F	Group G			
Conduit outlet bodies and junction boxes	CPS EJB EKC GUB GUJ EAB EJH GUA GUF LBH	Form 7 Series, etc., W Series	CPS EJB EKC GUB GUJ EAB EJH GUA GUF LBH	Same if splices, taps, etc.	Form 7 Series, etc., W Series		
Switches	EDS, EFD, EFS, FLS, FSPC, GUSC, OFC						
Panelboards	EDP ESPB GUSC	EDP ESPB GUSC D2PB	DLP, DVP				
Lighting fixtures	EV EVAM EVF Hazard-Gard RCDE	Vaporgard V Series VDB VMV VMVC VMVM VMVS FVN	DL DLAM EVF FDV		Vaporgard V Series VDB VMV VMVC VMVM VMVS FVN		
Fixture hangers	COUP CPS EAHC EC EFHC GUA	AHG EC GS UNE UNH UNJ UNJC	CPS EC EAHC EFHC GUA		AHG EC GS OSA	AHG AL EC GS OSA UNJ UNJC	
Plugs and receptacles	APJ, CES, CESD, CPH, CPP, CPS, EHS, ESW, BHR, BHP, DR, EHR, FP, FSQ, SRD, SP		Group G only APJ, BHR, BHP, DR, FP, FSQ, SRD, SP		Arktite Arktrol		
Interlocked plug receptacles	EPC, FSQ		Group G only FSQ, EPC, DBR			FSQ, EPC, DBR	
Control stations and pilot lights	EDS, EFD, EFS, EGP, EMP, EWC, OAC, OFC						
Industrial control	BMC, EDS, EFD, EFS, EPC, EPCB, FLF, FSPC, GUB, GUSC, OFC						
Circuit breakers	EDS, EFD, EPC, EPCB, FLB, GUSC		DVS, EDS, EFD, EPC, FLB, GUSC				
Telephones, instruments and signals	ECT, EKP, EMH, ESR, ET Telephones, ETH, GUB (plus WH (A.C. only) for Class II, Div. 2 and Class III, Div. 1 and 2)						

CLASS I INSTALLATIONS

(HAZARDOUS LOCATIONS)

DESIRED RESULTS:

To acquaint the apprentice with the safety devices used in hazardous locations called Class I.

INTRODUCTION:

The next three lessons are concerned with locations that, because of their nature, call for higher standards with respect to materials or for methods of installation, than are thought necessary in the general run of electrical wiring.

Class I deals with activities in which fire or explosion may result from gases or vapor.

METHODS OF REDUCING HAZARDS:

1. Placing seals between safe areas and perilous ones. Seal fittings are inserted in conduits to arrest sparks, using a suitable compound to accomplish the purpose. In some areas, where non-conductive dusts are present, a length of conduit may serve in place of the fitting.

2. Sparking devices are sealed off from runs of conduit which enter them. In some cases, the safety rule is met by placing sparking contacts in an oil bath or a hermetically sealed chamber.

3. Rigid conduit or mineral-insulated cable are prescribed as the only acceptable wiring methods in the majority of hazardous locations. Continued grounding must be assured by means of bonding and not by locknuts and bushings. Fittings must be explosion proof, dust-ignition proof, depending upon the nature of the particular hazard.

4. Motors within the scope of Class I, Division 1, must be explosion proof. Under Class I, Division 2, standard motors can be used if they have no sliding contacts. Motors within Class II and III must be totally enclosed or pipe ventilated.

   Extension cords are prohibited in certain occupancies and allowed in others only if approved for the particular service.

ESPECIALLY LISTED OCCUPANCIES:

1. In commercial garages, the NEC requires that plug receptacles within 18 inches of the floor be treated as subject to Class I, Division 2 requirements.

2. Unventilated garage pits, aircraft hangars, and gasoline dispensing islands are devoted as Class I, Division 1, to a height of 4 feet above grade.

3. Finishing processes, where paints, lacquers, or other flammable coatings are applied by spraying, dipping, brushing, or similar means, must be carried out under prescribed safeguards for electrical wiring and equipment. Of particular interest here, are electrostatic units which incorporate high-voltage transformers.

4. Anesthetizing locations of hospitals are deemed to be Class I, Division 1, to a height of 5 feet above the floor. Gas storage rooms are in the same designation.

   Special rules apply to lighting and surgical equipment within the operating room.

5. Theaters and motion picture studios are given adequate consideration in the NEC.

   Fires may occur suddenly from temporary wiring in connection with stage scenery, projection room equipment, arc lamps, and other portable devices.

6. Radio or television studios and receiving stations must be guarded from danger offered by high-voltage electronic wiring systems or equipment.

APPLICATION:

The students answer the questions on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the answers on the sheets.

CLASS II INSTALLATIONS

(HAZARDOUS LOCATIONS)

DESIRED RESULTS:

To acquaint the apprentice with the safety devices used in hazardous locations, called Class II.

INTRODUCTION:

If approved electrical devices of high quality are used but installed in a haphazard fashion and with no regard to the relation of one device to the other, the total load or the hazardous operating conditions, the complete installation may be dangerous. It is necessary that standardized methods be set up which have been found in practice to be safe.

These standardized methods that experiment and experience have shown to be correct are set down in a form which has come to be known as the National Electrical Code. (NEC)

Class II is concerned with the possibility of fire or explosion from dusts.

THE PURPOSES OF THE CODE:

It is well to review the purposes of the code as outlined in the following quotation from the Introduction of the Code.

a. The purpose of this Code is the practical safeguarding of persons and of buildings and their contents from hazards arising from the use of electricity for light, power, heat, radio, signaling, and for other purposes.

b. This Code contains provisions considered necessary for safety. Compliance therewith and proper maintenance will result in an installation, essentially free from hazard, but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical uses.

c. The Code is not intended as a design specification or an instruction manual for untrained persons.

The Code is revised from time to time but not necessarily at regular intervals. Usually the Code is reissued every two or three years. Each new Code carries changes in the

rules as compared with the previous issue. New sections or even new articles are added from time to time.

Give examples of installations that must be made in dust areas. Show how the fittings must be explosion-proof, dust-ignition proof, or dust tight, depending upon the nature of the hazard.

APPLICATION:

The students will answer the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

CLASS III INSTALLATIONS

(HAZARDOUS LOCATIONS)

DESIRED RESULTS:

To acquaint the apprentice with the safety devices used in hazardous locations called Class III.

INTRODUCTION:

Class III deals with activities in which fire or explosion may result from combustible fibers.

Electricity is a powerful force. Under control, it safely performs an endless variety of work for us; uncontrolled, it can lead to harm and damage. It is under control when the right kinds of materials are installed in the right way. It becomes uncontrolled when the wrong kinds of materials are used or when the right kinds of materials are wrongly installed.

Uncontrolled electric power can cause fires that can kill people and lead to a multitude of costly results. When these things happen, individuals and companies are the greatest suffers. Insurance companies also suffer losses which can result only in higher rates which individuals are called upon to pay. Insurance companies have led the way in setting up of minimum standards of quality in electrical materials as well as uniform methods of installation.

PRESENTING THE LESSON:

In the state of North Carolina, there are many examples of mills that store, process, and weave cloth that have hazardous locations that may cause fibers to burn. Locations in which ignitable fibers are merely stored or handled, other than in the actual process of manufacture are assessed to Class III, Division 2. This classification applies mostly to warehouses in which manufactured goods, materials in bales, are held for shipment to consumers.

Study Article 503 of the NEC for this assignment. Help the students to interpret the rules set up for wiring methods in the areas where combustible fibers are stored or processed.

APPLICATION:

Have the students to answer questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

COMMERCIAL GARAGES, REPAIR, AND STORAGE

RESIDENTIAL STORAGE GARAGES
(Special Occupancies)

DESIRED RESULTS:

To become acquainted with the National Fire Protection Association Standards in certain hazardous locations:

1. Used for service and repair operations in connection with self-propelled vehicles (automobiles, busses, trucks, tractors, etc.) in which volatile flammable liquids or gases are used for fuel or power.

2. Used for a residential storage garage of not more than three vehicles.

INTRODUCTION AND PRESENTATION:

The provisions of this article shall apply to occupancies which may be hazardous because of atmospheric concentrations of explosive gases or vapors, or deposits of materials which may be readily ignitable.

1. Commercial garages, repair, and storage. This classification shall include locations used for service and repair operations in connection with self-propelled vehicles in which volatile flammable liquids or gases are used for fuel or power. In these locations there are, or may be, more than three such vehicles stored at one time.

2. Residential storage garages. This classifies a residential storage garage as a building or room in which not more than three vehicles of the types described may be stored. The building will not normally be used for other than minor repairs or service operations on such stored vehicles.

APPLICATION:

Have the students complete the answers to the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers to the questions.

AIRCRAFT HANGARS

(Special Occupancies)

DESIRED RESULTS:

To acquaint the student with the classification that includes locations used for storage and servicing of aircraft.

INTRODUCTION:

Aircraft hangars are assigned similar regulations as commercial garages, but stricter protection. This classification shall include locations used for storage and servicing of aircraft in which gasoline, jet fuels, or other volatile flammable liquids are used.

PRESENTING THE LESSON:

Call attention to the following areas and have the students read each subject in the Code reference.

a. Hazardous Areas
b. Wiring and Equipment within Hazardous Areas
c. Wiring not within Hazardous Areas
d. Equipment not within Hazardous Areas
e. Stanchions, Rostrums, and Docks
f. Approved Seals
g. Aircraft Electrical Systems
   (1) De-Energizers
   (2) Energizers
h. Aircraft Battery
   Charging and control equipment
i. Mobile Servicing Equipment
j. Grounding

APPLICATION:

The students will answer the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers to the questions.

GASOLINE DISPENSING AND SERVICE STATIONS

(Special Occupancies)

DESIRED RESULTS:

To acquaint the apprentice with the classification that includes locations used for gasoline dispensing and service station work.

INTRODUCTION AND PRESENTATION:

Space in the immediate vicinity of a gasoline dispensing island is denoted as Class I, Division 1, to a height of 4 feet above grade. Bulk storage plants for gasoline are subject to comparable restrictions.

This classification shall include locations where gasoline or other volatile flammable liquids are transferred to the fuel tanks of self-propelled vehicles. Dispensing islands are areas extending 18 inches in all directions from the base of the pump. Where an individual pump or dispensing device is not mounted on an elevated island, an area extending 18 inches in all directions from the base of the pump shall be considered to be in dispensing island.

Call attention to the following areas and have the students read the restriction for each subject in the Code reference.

a. Hazardous Areas
b. Wiring and Equipment within and not within Hazardous Areas
c. Circuits Disconnects
d. Sealing
e. Grounding

APPLICATION:

Have the students answer the questions provided on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

BULK-STORAGE PLANTS

(Special Occupancies)

DESIRED RESULTS:

To acquaint the apprentice with the classification that includes locations where gasoline or other volatile flammable liquids are stored in tanks of one carload or more.

INTRODUCTION AND PRESENTATION:

Bulk storage plants for gasoline are subject to comparable restrictions as aircraft hangars. The products stored in these large tanks are usually distributed by tank truck.

Call attention to the following areas and have the students read the rules for each subject in the Code reference.

a. Hazardous Areas
b. Wiring and Equipment within and above Hazardous Areas
c. Underground Wiring
d. Sealing
e. Gasoline Dispensing
f. Grounding

APPLICATION:

Have the students answer the questions provided on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

FINISHING PROCESSES

(Hazardous Locations)

DESIRED RESULTS:

1. To acquaint the student with the hazardous areas where volatile flammable solvents or thinners are used.
2. To point out safeguards for finishing processes such as guarding, fire protection, posting warning signs, and a good maintenance program.

INTRODUCTION:

For further information regarding safeguards for finishing processes such as guarding, fire protection, posting of warning signs, and maintenance, see NFPA Standard for Spray Finishing Using Flammable and Combustible Materials No. 33-1369 and NFPA Standard for Dip Tanks Containing Flammable or Combustible Liquids No. 34-1966. For additional information regarding ventilation, see NFPA Standard for Blower and Exhaust Systems No. 91-1961.

PRESENTING THE LESSON:

Call attention to the important items listed in Article 516 and help the students to interpret these items that are directly related to wiring methods. The items of this Article are listed below under their general headings.

a. Definition
b. Hazardous Areas
c. Wiring and Equipment in Hazardous Areas
d. Fixed Electrostatic Equipment
e. Electrostatic Hand-Spraying Equipment
f. Powder Coating
g. Wiring and Equipment above Hazardous Areas
h. Grounding

Note:

It is important for the apprentice to know how to handle installations in plants that have these finishing processes because of the increasing number of installations in this part of the country.

APPLICATION:

The students should complete the assignment or worksheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

HEALTH CARE FACILITIES

(Special Occupancies)

DESIRED RESULTS:

1. To acquaint the apprentice with the code that includes general area wiring systems and essential electrical systems in locations where combustible anesthetics are used in health care facilities.
2. To study the definitions of terms used in health care facilities along with an understanding of the various electrical installations listed in the Code.

INTRODUCTION:

The 1971 Code devotes more space to these facilities than is generally given to a single subject. Also, many articles and interpretations have been published concerning this article in the Code.

The attached information sheets from recognized authorities have been prepared for the convenience of both instructor and students in helping to comprehend this task.

NOTE: Several members of the revision committee felt that much of this material should be left out of the lesson materials. They felt that the information concerning health care facilities is a problem for design engineers and manufacturing.

The chairman of the committee made the following statement concerning the subject. "I agree with the members of the committee; however, our electricians are charged with the correct and proper installation of the wiring systems. All the electrical health facilities are connected to this wiring. I want the apprentices to have a little knowledge of 'why' the job is done according to the N. E. Code. After all, this is the concern of related training."

PRESENTING THE LESSON:

Combustible anesthetics are gases or vapors which may form flammable or explosive mixtures with air, oxygen, or nitrous oxide.

Anesthetizing locations are areas in hospitals in which combustible anesthetics are or may be administered to patients. Such locations will include any area that may be used for the above purpose as operating rooms, delivery rooms, anesthesia rooms, any corridors

or utility rooms. Recovery rooms are not classed as anesthetizing locations unless used for the purpose.

Call attention to the following areas and have the students read the Code references for each subject:

1. General scope and definitions
2. General area wiring systems
3. Essential electrical systems
4. Electrically susceptible patient areas
5. Inhalation anesthetizing locations

In a health care facility, the emergency system is divided into three main divisions:

1. Life safety branch
2. Critical branch
3. Life support branch

Try to present the wiring problems of the electrician working in a health facility in organized manner. Stress the importance that each area is installed separately and each area has its particular wiring methods and problems.

Stress the wiring of hazardous areas, the need, and the selection of types and compounds used in sealing fittings. Select other important areas to stress in the lesson.

APPLICATION:

The students will answer the questions on the assignment sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

FUNDAMENTALS OF MOTOR CONTROL

DESIRED RESULTS:

To study the meaning of motor control and the basic differences in manual, semi-automatic, and automatic controls.

INTRODUCTION:

Much of the inside wireman's work is concerned with motors and controllers. It is essential that he acquire a general knowledge of motor types, controls, and other characteristics.

With the advent of mass production, down came the line shaft and the electric motors were installed on individual machines. This change allowed more frequent and more rapid starts, stops, and reversals of the machine. Once the drive motor was put on the machine with the sole function of operating one piece of equipment it was possible to introduce some automatic operations.

Now, in our industrial plants, the operator sets up the original process, and the operations are carried out automatically. These automatic operations are dependent upon motor and machine control. Thus, the modern machine consists of three divisions: (1) the machine, (2) the motor, and (3) the controls.

PRESENTING THE LESSON:

A. Discussion
   1. What is the meaning of motor control?
   2. What is an electric controller?
   3. Discuss the basic differences in manual, semi-automatic, and automatic controls.
   4. Discuss the construction of several controllers.

B. Information sheets: Review the attached information sheets
   1. Motor control trouble--remedy table
   2. Water soaked motor control--general recommendations

APPLICATION:

Have the student complete the assignment sheets for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

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INFORMATION SHEET LESSON C-18

Motor Control Trouble — Remedy Table

The following table lists troubles encountered with motor control, their causes and remedies. This table is of a general nature and covers only the main causes of trouble.

Misapplication of a device can be a cause of serious trouble, however rather than list this cause repeatedly it should be noted here that **misapplication is a major cause of motor control trouble and should always be questioned when a device is not functioning properly.**

Actual physical damage or broken parts can usually be found quickly and replaced. Damage due to water or flood conditions require special treatment. See page 3 for recommendations for renovating water soaked motor control.

TROUBLE	CAUSE	REMEDY
	Magnetic Contactors and Starters	
CONTACTS		
Contact Chatter	1. Broken shading coil.	1. Replace.
	2. Poor contact in control circuit.	2. Improve contact or use holding circuit interlock (3 wire control).
	3. Low voltage.	3. Correct voltage condition. Check momentary voltage dip during starting.
Welding or Freezing	1. Abnormal inrush of current.	1. Use larger contactor or check for grounds, shorts or excessive motor load current.
	2. Rapid jogging.	2. Install larger device rated for jogging service or caution operator.
	3. Insufficient tip pressure.	3. Replace contact springs; check contact carrier for deformation or damage.
	4. Low voltage preventing magnet from sealing.	4. Correct voltage condition. Check momentary voltage dip during starting.
	5. Foreign matter preventing contacts from closing.	5. Clean contacts with carbon tetrachloride, contactors, starters, and control accessories used with very small current or low voltage, should be cleaned with carbon tetrachloride and then with acetone to remove the carbon tetrachloride residue.
	6. Short circuit.	6. Remove short fault and check to be sure fuse or breaker size is correct.
Short Tip Life or Overheating of Tips	1. Filing or dressing.	1. Do not file silver tips. Rough spots or discoloration will not harm tips or impair their efficiency.
	2. Interrupting excessively high currents.	2. Install larger device or check for grounds, shorts or excessive motor currents.
	3. Excessive jogging	3. Install larger device rated for jogging or caution operator.
	4. Weak tip pressure.	4. Replace contact springs; check contact carrier for deformation or damage.
	5. Dirt or foreign matter on contact surface.	5. Clean contacts with carbon tetrachloride.
	6. Short circuits.	6. Remove short fault and check to be sure fuse or breaker size is correct.
	7. Loose connection.	7. Clean and tighten.
	8. Sustained overload.	8. Install larger device or check for excessive motor load current.
COILS		
Open Circuit	1. Mechanical damage.	1. Handle and store coils carefully.
Roasted Coil	1. Over voltage or high ambient temperature.	1. Check application and circuit.
	2. Incorrect coil.	2. Check rating and if incorrect, replace with proper coil.
	3. Shorted turns caused by mechanical damage or corrosion.	3. Replace coil.
	4. Under voltage, failure of magnet to seal in.	4. Correct system voltage.
	5. Dirt or rust on pole faces increasing air gap.	5. Clean pole faces.

TROUBLE	CAUSE	REMEDY
	Magnetic Contactors and Starters	
OVERLOAD RELAYS		
Tripping	1. Sustained overload.	1. Check for grounds, shorts or excessive motor currents.
	2. Loose connection on load wires.	2. Clean and tighten.
	3. Incorrect heater.	3. Relay should be replaced with correct size heater unit.
MAGNETIC & MECHANICAL PARTS		
Noisy Magnet	1. Broken shading coil.	1. Replace shading coil.
	2. Magnet faces not mating.	2. Replace magnet assembly or realign.
	3. Dirt or rust on magnet faces.	3. Clean and realign.
	4. Low voltage.	4. Check system voltage and voltage dips during starting.
Failure to Pick-up and Seal	1. Low voltage.	1. Check system voltage and voltage dips during starting.
	2. Coil open or shorted.	2. Replace.
	3. Wrong coil.	3. Check coil number.
	4. Mechanical obstruction.	4. With power off, check for free movement of contact and armature assembly.
Failure to Drop-Out	1. Gummy substance on pole faces.	1. Clean with carbon tetrachloride.
	2. Voltage not removed.	2. Check coil circuit.
	3. Worn or rusted parts causing binding.	3. Replace parts.
	4. Residual magnetism due to lack of air gap in magnet path.	4. Replace worn magnet parts.
PNEUMATIC TIMERS		
Erratic Timing	1. Foreign matter in valve.	1. Replace timing head complete or return timer to factory for repair and adjustment.
Contacts Do Not Operate	1. Maladjustment of actuating screw.	1. Adjust as per instruction in service bulletin.
	2. Worn or broken parts in snap switch.	2. Replace snap switch.
LIMIT SWITCHES		
Broken Parts	1. Overtravel of actuator.	1. Use resilient actuator or operate within tolerances of the device.
MANUAL STARTERS		
Failure to Reset	1. Latching mechanism worn or broken.	1. Replace part.
COMPENSATORS (MANUAL)		
Welding of Contacts on Starting Side	1. Inching, jogging and operating handle slowly.	1. Excessive inching and jogging not recommended (caution operator) move handle swiftly and surely to start position.
Welding of Contacts Running Side	1. Moving handle slowly to run position.	1. Move handle swiftly and surely to run position as motor approaches full speed.
	2. Lack of sufficient spring pressure.	2. Replace contacts and contact springs.
Damaged or Burned Transformer	1. Repeated inching and jogging.	1. Excessive inching and jogging not recommended (caution operator).
	2. Holding handle in start position for long periods.	2. Hold handle in start position only until motor approaches full speed.

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INFORMATION SHEET LESSON C-18

Water-Soaked Motor Control

GENERAL RECOMMENDATIONS

1. **CLEANING** — All equipment should be hosed down and scrubbed with a stiff brush. Water pressure should be limited to 25 pounds per square inch maximum on insulating parts. Water temperature should not exceed 90 degrees C., 194 degrees F. maximum. Carbon tetrachloride or any approved solvent should be used for a final cleaning of insulating surfaces, contact tips and magnet pole faces. Contact tips should also be cleaned with acetone to remove the film left by carbon tetrachloride. Steam cleaning should not be used except on cabinets and enclosures from which the interiors have been removed.

2. **DRYING** — Drying in the sun or in a warm, dry room will take about 2 to 4 days. If heat is used for drying, it should be limited to about 212 degrees F., preferably starting at about 150 degrees or lower and gradually building up to 212 degrees F. Plaster drying equipment, electric heaters, baking ovens may be used. Approximately 24 hours drying by this method should generally be sufficient. For equipment operating at voltages above 250, greater caution in drying and cleaning should be taken, because of the greater susceptibility to insulation breakdown.

3. **LUBRICATION** — All mechanical joints, sliders, bearings, and moving parts should be cleaned and lubricated with any good lubricating oil. Exception: NO OIL SHOULD BE APPLIED TO CONTACT SURFACES OR MAGNET POLE FACES.

4. **FINAL CHECK** — Test insulation resistance with megger or ohmmeter. A 500 volt or 1000 volt megger is recommended; higher voltages are not suitable for testing controls rated at 600 volts. One megohm is recommended as minimum resistance but equipment may operate satisfactorily with less. In operation, normal drying will cause this resistance value to increase. Restore power to one device at a time, watching for evidence of leakage, spitting, or smoking. For all equipment passing up to this point, load may then be restored, watching for spitting or smoking at contacts. Check to be sure that no open circuit conditions exist

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SPECIFIC RECOMMENDATIONS

1. **COILS AND TRANSFORMERS** — Wash with clean hot water and dry by any of methods listed above, or by applying a low voltage (about 10% of rated voltage) to the coil for 2 or 3 hours. Magnet armature should be in open position or coil should be removed from magnet. For drying D. C. coils by this method, a resistor in parallel with the coil is recommended to provide a discharge path for the kick voltage induced when the circuit is opened. Special care should be taken to dry out D. C. coils, since in operation, the inductive voltage may be several times normal voltage. Check with the megger for insulation resistance (one megohm).

2. **MAGNETS** — Wash, clean, and dry with cloth or air hose. Lubricate bearings, pins, etc. Clean magnet pole faces with carbon tetrachloride to remove oil film and surface dirt which might cause the armature to stick.

3. **CONTACT SURFACES** — Clean tips with carbon tetrachloride, then with acetone to remove the carbon tetrachloride film. Filing the tips is not recommended, but may be used if the surface is very difficult to clean. Do not use sandpaper or emery-cloth which would deposit grit on the tips. Small contacts can be "filed" by rubbing Kraft paper over the surface. Particular care should be taken with small contacts such as electrical interlocks, overload relays, and push buttons.

4. **INSULATING PARTS** — All surfaces of contact blocks arc chamber covers, yoke bars, overload relay blocks, etc. should be cleaned with carbon tetrachloride, particularly between poles, and dried carefully. Surface drying is generally sufficient for glazed porcelain, melamine, and non-absorbent plastics. Unglazed porcelain, bakelite, and Rostone absorb water and should be baked to dry thoroughly. (Rostone is the cold molded material used for contact blocks on Size 1, 2, and 3 starters.) Check with megger from pole to pole and from each pole to ground, for one megohm minimum insulation resistance.

5. **THERMAL OVERLOAD RELAYS** — Melting alloy type relays should be partially disassembled to permit cleaning contacts and moving parts. Lubricate to be sure parts can move freely. Clean heater surfaces to permit normal heat radiation. Bimetallic type overloads should not be taken apart, because of their intricate assembly. For emergency service, they can be used if they check satisfactorily, mechanically and electrically. To check mechanically, remove heater unit and press downward on lower end of bimetal strip with a screwdriver; this should trip the relay and open control circuit contacts. Ultimately, bimetal overload relays should be replaced.

6. **SNAP SWITCHES** — (Class 9007, Type A0) snap switches should generally be replaced as soon as possible. For temporary use, shake out any water trapped inside, blow out with an air hose, and bake to dry. Check circuit continuity. Dirt inside the case may prevent contacts from closing properly and cause excessive wear on the toggle mechanism. It is generally impractical to attempt opening the case to clean it out.

7. **PNEUMATIC TIMERS** — Timer heads should not be taken apart. It is recommended that the timer be replaced or returned to the factory for repair. For temporary use, dry timer thoroughly and treat coil, magnet, and snap switch as recommended. Check timing operation. Timer should be suitable for limited use, but will probably not be very accurate, due to dirt in the valves.

CONTROL OF MOTOR STARTING

DESIRED RESULTS:

To acquaint the student with the basic principles and general types of automatic motor controls in a simplified manner.

INTRODUCTION:

The subject of motor controllers is of great importance to the industrial electrician. He is often called upon to connect, disconnect, or troubleshoot them. It is necessary that he have a sound knowledge of the principles upon which they operate.

The most common of the controllers is the magnetic switch or across-the-line starter. This starter, combined with pilot devices, can give full protection to the motor and be fully automatic in operation. The student should make sure he understands the purpose of each component. Circuits containing plugging relays should be analyzed and the essential ones memorized. It is not advisable to try memorizing the complicated circuits of reversing or multi-speed motors. However, the material relating to these components should be read carefully.

PRESENTING THE LESSON:

A. Discuss the following types of motor starting with the use of diagrams:
   1. Full-voltage starting
   2. Reduced-voltage starting
   3. Starting squirrel-cage motors
   4. Starting wound-rotor motors
   5. Starting synchronous motors

B. Discuss the selection of starting controllers:
   1. Name the two types of starting controls.
   2. How many types of protection are there for motors?
   3. Do the running conditions of the motor affect the type of control to be used on a motor?
   4. What is the difference between an automatic and a semi-automatic controller?
   5. Summarize the factors needed to be considered when selecting starting controllers.

APPLICATION:

The students will complete the assignment sheets for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

CONTROL COMPONENTS

DESIRED RESULTS:

To give the student an insight into the many variations in devices used to control the functions of motors.

INTRODUCTION:

The selection of control components is carefully made after it has been decided what functions of control are needed for a machine. It should be remembered that a motor can perform only as well as the components in its control circuit. The fact that a certain component is a high quality product does not necessarily mean that it will perform well in a particular circuit. The component must be selected to fit the motor to be controlled and the function to be performed.

PRESENTING THE LESSON:

Discussion Questions:

1. What functions of control are intended to be performed by switches and breakers?
2. Compare a contactor and an across-the-line motor starter.
3. What is meant by a relay? What is required to operate a voltage relay?
4. What is meant by the terms pull-in current, drop-out current, and differential used in connection with current relays.
5. Name two uses for a frequency relay. What are the two basic methods of delaying the closing or opening of the time-delay relays.
6. What is the chief advantage to using an automatic motor starter instead of a manual motor starter? What is meant by clapper-type and solenoid type contact arrangements?
7. Name the three basic magnetic [illegible]es used on modern motor starters.
8. What is the basic difference between a motor starter and a motor controller?
9. What is the common name for a manual reduced-voltage starter? Name three basic methods of obtaining reduced-voltage starting.
10. What is meant by the following:
    a. Definite time control
    b. Current-limit control
    c. Sequence speed control
    d. Selective speed control
    e. Automatic speed control
    f. Reversing starter

APPLICATION:

The students should complete the assignment sheets.

CHECKING AND FOLLOW-UP:

Check the answers. Help those that have trouble finding the correct answers.

PILOT DEVICES

DESIRED RESULTS:

1. To acquaint the student with the basic types of control components.
2. The student should be able to look at a strange control device and analyze its function both mechanically and electrically.

INTRODUCTION:

All components used in motor-control circuits are classed as either primary control devices or pilot control devices. A primary control device connects the load to the power line, such as a motor starter or controller: they may be manual or automatic. Pilot control devices are those which control or regulate the primary control devices. Pilot devices are such components as push buttons, float switches, pressure switches, limit switches, and thermostats. We will cover the most common and frequently used types in this lesson.

PRESENTING THE LESSON:

1. Describe various pilot devices and their uses. The requirements of pilot devices vary greatly with their function and their proposed use.
2. Demonstrate samples of pilot devices available. Show how they are installed and ways to "troubleshoot" when the unit will not function.

APPLICATION:

Have the students complete the questions on the assignment sheets.

CHECKING AND FOLLOW-UP:

Check the answers on the assignment sheets.

CONTROL-CIRCUIT DIAGRAMS

DESIRED RESULTS:

To learn the basic symbols that are used on prints to express the meaning and purpose of the circuit.

INTRODUCTION:

Until the electrician masters the control diagrams, he will be dependent upon someone else for most of his information. This lesson deals with the written language of control and control circuits. It will be necessary for the apprentice to learn the basic symbols in order to understand the details of the schematic control diagrams. When we learned to read English, we first learned the 26 letters of the alphabet that are used to form all the words and sentences. The same thing is true in learning a graphical language. There are only a few basic symbols that are used to express the meaning and purpose of the control circuit.

PRESENTING THE LESSON:

1. Use Fig. 5-1, page 91 for a drill on recognizing the basic symbols.
2. The control diagram is the written language of control circuits and it takes several different forms to fit the needs. Study the three general types of control diagrams used in the text.
3. Show how a schematic diagram is developed from a wiring diagram. Wiring diagram from the schematic.
4. If possible, have available control-circuit diagrams used in the local area for review by the class.
5. Discuss the adding of circuit elements, such as a limit switch, float switch, or push button to an existing circuit.
6. Summarize the use of schematic and wiring diagrams as presented in this lesson.

APPLICATION:

Have the students complete the questions on the assignment sheets.

CHECKING AND FOLLOW-UP:

Check the sheets.

DEVELOPMENT OF CONTROL CIRCUITS

DESIRED RESULTS:

1. To acquaint the student with the principles involved in the development of control circuits.
2. To have the student practice the development of a circuit adding one function at a time.

INTRODUCTION:

In the development of control circuits, they are seldom drawn or designed as a complete unit. They are developed one step at a time, adding only the components necessary to perform that function. The designer of a circuit should have all the control functions in mind when he starts. He should analyze the circuit after each addition to check that it does not interfere with previous operations and that it will perform the function intended. The greatest danger in developing control circuits is to attempt to draw a complete circuit at one time. Therefore, it cannot be overstressed that the step-by-step method of developing control circuits will lead to very few errors. It will save many hours of "troubleshooting" trying to find out why a circuit did not function after it was wired.

PRESENTING THE LESSON:

1. Discuss the basic two-wire and three-wire circuits in the development of control circuits.
2. Using a schematic diagram, show the simplest method for the development of a control circuit by starting with the coil and the overloads.
3. Review with the students the development of illustrated circuits No. 1-8 given in the text.

APPLICATION:

Have the students complete the problems on the assignment sheet.

CHECKING AND FOLLOW-UP:

Check the assignment sheets.

MATERIAL TAKE-OFF

Listed below is the material required for the lighting and receptacle outlets:

11	Lighting outlet boxes	
11	Bar hanger (with fixture stud)	
18	Switch boxes w-nails (12 S.P. switches and 6 3-way switches)	
19	Receptacle boxes w-nails	
850'	14-2 Romex w/ground (40 outlets x 20' each)	(12 lights, 17 receptacles) (11 S.P. switches - 2 fans)
100'	12-2 Romex w/ground	(3 receptacles in kitchen and dining room) + GFI receptacles in baths and outdoors (3 outlets x 20' each)
90'	14-3 Romex w/ground	(6 outlets x 15' each)
230	Romex staples (1040' total wire ÷ 4.5' = 230)	
75	Sta-kons or wire nuts (splices in boxes and fixture splices)	
19	Duplex receptacles	
3	GFI receptacles - I.W.P. (with Plates)	
19	Duplex receptacle plates	
11	Single pole switches	
6	3-way switches	
7	1-gang switch plates	
5	2-gang switch plates	
51	Bonding clips or screws to ground boxes	
5	1/2" Romex connectors (for panel - 2 small appliance circuits, 3 general lighting circuits)	
2	20 amp 1-pole breakers	
3	15 amp 1-pole breakers	

Listed below is the material required for the major appliance circuits and outlets:

Dishwasher

30'	12-2 Romex w/ ground
6	Romex staples
1	Receptacle box w-nails
1	Receptacle (20 amp 115 volt)

Dishwasher (Continued)

1	Receptacle plate
1	1/2" Romex connector (at panel)
1	20 amp 1-pole breaker

Refrigerator

20'	12-2 Romex w/ground
4	Romex staples
1	Receptacle box w-nails
1	Receptacle (20 amp 115 volt)
1	Receptacle plate
1	1/2" Romex connector (at panel)
1	20 amp 1-pole breaker

Washer

15'	12-2 Romex w/ground
4	Romex staples
1	Receptacle box w-nails
1	Receptacle (20 amp 115 volt)
1	Receptacle plate
1	1/2" Romex connector (at panel)
1	20 amp 1-pole breaker

Water Heater

20'	10-2 Romex w/ground
4	Romex staples
2	1/2" Romex connectors
2	Wire nuts
1	30 amp 2-pole breaker

Dryer

10'	10-3 Romex
2	Romex staples
1	Surface dryer receptacle
1	1/2" Romex connector
1	30 amp 2-pole breaker

Range

25'	6/3 service cable
6	Nail straps
1	Surface range receptacle

Range (Continued)

1	3/4" cable connector (at panel)
1	50 amp 2-pole breaker

Bathroom Exhaust Fans (on General Lighting Circuits)

4	1/2" Romex connectors
4	Wire nuts

Listed below is the material required for the baseboard heating system:

4	500 watt baseboard heaters
2	750 watt baseboard heaters
1	1000 watt baseboard heater
3	1500 watt baseboard heater
1	500 watt kick space heater
7	Switch boxes w-nails for thermostats
7	Line voltage heat thermostats (wall mounted)
11	Chase nipples or connectors for entering heaters
450'	12-2 Romex w/9 (18 outlets x 25' each) (11 heaters + 7 thermostats)
100	Romex staples
44	Screws for fastening heater to walls
43	Sta-kons or wire nuts (heater connections and joints in thermostats)
3	1/2" Romex connectors (at panel)
3	20 amp 2-pole breakers

Listed below is the material required for the ceiling cable heating system:

2	1400 watt heat cable
1	200 watt heat cable
1	400 watt heat cable
1	1000 watt heat cable
1	2000 watt heat cable
1	3000 watt heat cable
5000	Heat cable staples (for fastening cable to lath or sheetrock)
7	Switch boxes w-nails for thermostats
7	Line voltage heat thermostats (wall mounted)
175'	12-2 Romex w/9 (7 thermostat outlets x 25' each)
50	Romex staples
21	Sta-kons or wire nuts (joints in thermostat)
3	1/2" Romex connectors (at panel)
3	20 amp 2-pole breakers

Listed below is the material required for the electric furnace heating system:

1	60 amp 2-pole breaker
25'	6/3 copper or 4/3 alum. service cable
2	3/4" service cable connectors
6	Nail straps
1	60 amp 2-pole no fuse disconnect switch
4	Screws to mount switch
3'	3/4" Greenfield (flexible metal conduit)
2	3/4" Greenfield connectors
10'	#6 THHN wire
5'	#10 THHN wire green (to bond around Greenfield)
20'	18-5 thermostat wire
4	Insulated staples

Listed below is the material required for the pad mounted A/C condenser unit:

1	30 amp 2-pole breaker
20'	10-2 Romex w/ground
5	Romex staples
2	1/2" Romex connectors
1	30 amp 2-pole no fuse raintight disconnect switch
4	Screws to mount switch
3'	1/2" liquid-tight Greenfield
2	1/2" liquid-tight Greenfield connectors
10'	#10 TW wire
5'	#10 TW wire (green) to bond around Greenfield
30'	18-2 thermostat wire (from furnace to condenser)

Listed below is the material required for the two window A/C units:

<u>8,000 BTU 115 Volt</u>

20'	12-2 Romex w/ground
4	Romex staples
1	Receptacle box w-nails
1	Receptacle (20 amp 115 volt)
1	Receptacle plate
1	1/2" Romex connector (at panel)
1	20 amp 1-pole breaker

<u>15,000 BTU 230 Volt</u>

20'	12-2 Romex w/ground
4	Romex staples

15,000 BTU 230 Volt (Continued)

1	Receptacle box w-nails
1	Receptacle (20 amp 230 volt)
1	Receptacle plate
1	1/2" Romex connector (at panel)
1	20 amp 2-pole breaker

Listed below is the material required for the service, panel, and grounding:

Panel

1	1-phase 3 wire with 125 amp main breaker and 24 1-pole breaker spaces
25'	3 conductor 125 amp service cable (3- 1/0 aluminum) or (3- #2 copper)
2	1 1/2" cable connectors
1	1 1/2" watertight cable connector (top of meter base)
1	Entrance cap or weatherhead
8	Service cable straps
16	Screws for straps and mounting panel and meter base
20'	#6 bare copper wire for (grounding conductor from panel to cold water pipe) and (driven ground)
2	Ground clamps
1	8' ground rod

MATERIAL TAKE-OFF

1. From the house plan list the material you would need to rough the job in, trim it out, and leave it ready for occupancy. The owner will supply the fixtures. Material should be listed for the following general uses:

    a. Lighting and receptacle outlets
    b. Major appliance outlets
    c. Heating system (one system only)
    d. Air conditioning system (one method only)
    e. Panel and service

2. Types of material to be listed should include:

    a. Boxes
        (1) Outlet - fixture stud
        (2) Switch
        (3) Receptacle
    b. Cable - size and number of conductors
    c. Devices and plates
    d. Fastening materials - screws, anchors, straps, staples
    e. Panel - size main bus, number and size of branches
    f. Service - cable, grounding conductors, ground rod or pipe, entrance cap, meter box-pick up from utility

NOTE: These lists were circulated out and compiled by a contractor's estimator who specializes in single and multi-family dwellings. A student error of 10% would be considered reasonable due to a lack of experience.

No one student should need more than 5 of the 8 material list categories to complete one method of total electric comfort conditioning the residence (i.e., only one method of heating and one method of cooling plus lighting and receptacle outlets, major appliance circuits, and the panel, service, and grounding).

ESTIMATING

DESIRED RESULTS:

1. To present the major items used to estimate the cost of making a given electrical installation.
2. To discuss the methods of calculating the cost of materials, labor, tools, and equipment, etc., for various installations.
3. To appreciate the position of management to make good estimates of all items in installations in order to realize profits.

INTRODUCTION:

This unit is presented to give the apprentice an appreciation of costs involved in electrical installations rather than to teach how to make the calculations. Note that all of the items involved have some built-in variables, but generally it takes a set amount of materials to build a given electrical installation. Introduce some of the variables used in these estimates.

PRESENTING THE LESSON:

Discuss what is meant by an electrical installation estimate. List some of the items included in an estimate. Point out the items that make an accurate estimate. How is management able to make profits on these electrical installations?

Discuss the items that are deducted from a worker's check. Show why there are wide differences in "bid prices" submitted by contractors or companies. How do the companies calculate to realize profits on these jobs?

APPLICATION:

Have the students complete the worksheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

ESTIMATING

An estimate is an accurate and factual appraisal of the probable cost of doing a job.

The cost of doing a job consists of a number of items; a few major ones are:

a. Material
b. Labor
c. Taxes and insurance
d. Bonds
e. Tools and equipment
f. Job and office overhead
g. Profit

All of the above items have some built-in variations, but generally it takes a set amount of material to accomplish a given electrical job.

Once an accurate material list for a job is made, an estimate of the man-hours needed to install this work must be made. The tools and equipment needed to do the job must be figured into the estimate, along with taxes, insurance, bonds, and the non-production labor (office workers--payroll, billing, estimating, warehousemen, engineers, accounting, secretaries, salesmen, etc., who keep the wheels turning). To this list of figures is added profit.

Notice that ar estimate is a group of variables stacked one upon another, yet all based on the quantity of material necessary to make the electrical installation.

Your job as an electrician is to be able to take the material required to do the job and install it within the time allotted. You must be able to see the job from the plans the same way the engineer designed the job and as the estimator saw it when he took the job off the plans.

To install the work, you must know the many component parts which make up the complete installation--where they fit into the work, how they are fastened in place, and how to interconnect them electrically. Without all of this knowledge, the job cannot be done to fit the plans, the budget, the N. E. Code requirements, and the user's needs.

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ASSIGNMENT REFERENCES

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*Note #1: Page Numbers Listed
*Note #2: Article Numbers Listed
*Note #3: Division and Section Numbers Listed
*Note #4: Chapter and Page Numbers Listed
*Note #5: Basic Math References in left column are 2nd Edition; Basic Math Ref. in last column are 3rd Edition, 1972.

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ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	ELECTRIC MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
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(Continued) ASSIGNMENT NAME (TITLE)	LESSON NO.	BASIC MATH	BASIC ELECTRICITY	1978 N.E. CODE	AMERICAN ELECTRICIAN'S HANDBOOK	ELECTRIC MOTOR CONTROL FUNDAMENTALS	OTHER MATERIALS
Job Management	D-26						
Effective Foremanship	D-27						

CABLE TRAY

DESIRED RESULTS:

1. To study the requirements of the Code concerning the support of the conductor assemblies.
2. To become acquainted with approved materials used for the tray.
3. To learn the approved and non-approved areas for using cable tray and how they should be installed.

INTRODUCTION AND PRESENTING THE LESSON:

It is the intent of this Article to make sure that the trays have mechanical strength, good finish, and are adequately protected against corrosion.

The cable trays, ventilated or non-ventilated, shall be made of non-combustible materials. They may be used for the support of the conductor assemblies described in the Code.

APPLICATION:

Have the students complete the assignment questions for this lesson.

CHECKING AND FOLLOW-UP:

Check the papers.

NONMETALLIC EXTENSIONS

DESIRED RESULTS:

To become acquainted with the Code requirements concerning nonmetallic extensions.

INTRODUCTION:

Nonmetallic surface extensions are two-wire assemblies designed to be fastened to the wall or baseboard. This will supply additional convenience outlets from an existing convenience outlet. The existing outlet has to be supplied from some other approved method of wiring. Examples of two types of nonmetallic surface extensions will be given here.

1. The electrotrim consists of an assembly of two No. 14 rubber-covered wires without braid sewed into a specially treated fabric. Tacks or small nails may be used in the under layer of the fabric between the wires for securing the assembly in place. The top layer of fabric forms a flap and covers the heads of the tacks. A plug is fastened to the end of the strip and plugged into the existing outlets.

2. Adhere is another type of extension wiring consisting of a high grade rubber molding in which two No. 14 bare stranded conductors have been placed. A special cement is supplied by the manufacturer by means of which the assembly can be firmly secured to the surface of almost any material used for interior finish. Using Adhere, the existing outlet is removed and remounted on a special 1/2 inch box extension into which the strips run.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

UNDERPLASTER EXTENSIONS

DESIRED RESULTS:

To study the Code regulations concerning underplaster extensions.

INTRODUCTION:

Underplaster extensions are wiring systems laid in a channel cut in the plaster surface of a wall, down to the face of masonry or other wall material. Rigid or flexible metal conduit, armored cable, electrical metallic tubing, or metal raceways approved for the purpose are laid in the channel and secured to the surface of the wall or ceiling structure. Provision for outlets is made by inserting shallow outlet boxes in the run of conduit, cable, tubing, or raceway. After the system has been secured in the channel, it is plastered over flush with the wall or ceiling surface.

The National Electrical Code allows such changes to be made in buildings of fire resistive construction.

DISCUSSION QUESTIONS:

1. When can an underplaster extension be installed?
2. What materials are used for underplaster extensions?
3. List the boxes and fittings specified in Article 370 to be used with underplaster extensions.
4. Discuss the installation of an underplaster extension.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

SURFACE METAL RACEWAYS

DESIRED RESULTS:

To become acquainted with the use, installation and construction specifications of surface metal raceways.

INTRODUCTION:

In surface metal-raceway wiring the wires are supported in a thin sheet-steel casing. The raceway is installed exposed, being mounted on dry walls or ceilings. The sheet-steel casing, called metal raceway or metal molding, is made with a flattened-oval or rectangular cross section. Most types of molding are made in two parts, a trough or base which is fastened to the wall or ceiling and a capping which is snapped on the base. One type of surface metal raceway is manufactured with the capping crimped on the base at the factory. With this type, the wires must be pulled through the raceway from outlet to outlet as in the conduit-wiring method. Provisions for outlets or switches are made by means of special fittings inserted in the runs of molding.

DISCUSSION QUESTIONS:

1. List places where surface metal raceway should not be used.
2. Discuss the size and number of conductors to be installed in any raceway.
3. How should surface metal raceways be extended through walls and floors?
4. Discuss the use of combination raceways.
5. What are the general construction specifications for surface metal raceways and the fittings.?

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

MULTIOUTLET ASSEMBLY

DESIRED RESULTS:

To understand the requirements of the Code concerning the installations of multioutlet assembly.

INTRODUCTION:

Installations of multioutlet assembly shall comply with applicable provisions of Article 300. Refer to Article 100 for definitions. Stress that multioutlet assembly may be installed in dry locations.

DISCUSSION QUESTIONS:

1. Review the definition of multioutlet assembly.
2. Discuss the various uses of multioutlet assembly.
3. Why is the multioutlet assembly not installed in any hazardous location?

APPLICATION:

Have the students complete the questions on the worksheet.

CHECKING AND FOLLOW-UP:

Check the answers.

UNDERFLOOR RACEWAYS

DESIRED RESULTS:

To study the Code requirements concerning the use and installation of underfloor raceways.

INTRODUCTION:

Underfloor raceway systems are used principally in office buildings for the installation of the wiring for telephone and signal systems, and for convenience outlets for electrical office machines. They provide a flexible system for the location of outlets to accommodate the rearrangement of furniture and partitions. The National Electrical Code allows their use only in buildings of fireproof construction when embedded in the concrete or in concrete fill of the floors. Their installation is allowed only in dry locations which are free from corrosive or hazardous conditions. No wires larger than the maximum size approved for the particular raceway should be installed. The voltage of the system must not exceed 600 volts. The ducts for this raceway system are made of either fiber or steel.

DISCUSSION QUESTIONS:

1. In general, how are underfloor raceways installed?
2. List two places where underfloor raceways should not be installed.
3. Discuss the size and number of conductors allowed in a raceway.
4. Discuss how to install (a) junction boxes, (b) inserts, and (c) wall outlets.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

CELLULAR METAL FLOOR RACEWAYS

DESIRED RESULTS:

To become acquainted with the use and installation of conductors in cellular metal floor raceways.

INTRODUCTION:

The term cellular metal floor refers to a type of floor construction designed for use in steel-frame buildings. The members supporting the floor between the beams consist of sheet steel rolled into shapes which are combined to form cells. These passageways extend across the building and are of various shapes and sizes, depending upon the structural strength required. These cellular members can be adapted as underfloor raceways with the use of suitable fittings.

DEFINITIONS:

1. A cellular metal floor raceway consists of the hollow spaces of cellular metal floors, together with suitable fittings, which may be approved as enclosures for electrical conductors.

2. A cell is a single, enclosed tubular space in a cellular metal floor member. The axis of the cell will run parallel with the axis of the metal floor member.

3. A header is a transverse raceway for electrical conductors from which they are distributed to the cells.

APPLICATION:

Have the students answer the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

CELLULAR CONCRETE FLOOR RACEWAYS

DESIRED RESULTS:

To become acquainted with the scope, use, and installation of conductors in precast cellular concrete floor raceways.

INTRODUCTION:

The title Precast Cellular Concrete Floor refers to a type of floor construction designed for use in steel frame, concrete frame, and wall bearing construction. The precast reinforced concrete floor members form the structural floor and are supported by beams or bearing walls. These precast floor members have hollow voids which form smooth round cells. The cells are of various sizes depending on the size of floor member used. The cells with the use of suitable fittings can be adapted for underfloor raceways. This floor is fire-resistant and requires no additional fireproofing.

DEFINITIONS:

1. For the purposes of this Article, precast cellular concrete floor raceways shall be defined as the hollow spaces in floors constructed of precast cellular concrete slabs. These contain suitable metal fittings designed to provide access to the floor cells.

2. A cell shall be defined as a single, enclosed tubular space in a floor made of precast cellular concrete slabs. The direction of the cell being parallel to the direction of the floor member.

3. Header ducts shall be defined as transverse metal raceways for electrical conductors. These raceways furnish access to predetermined cells in the concrete floors. They provide for the installation of electrical conductors from a distribution center to the floor cells.

APPLICATION:

Have the students complete the Assignment questions.

CHECKING AND FOLLOW-UP:

Check the questions.

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BUSWAYS

DESIRED RESULTS:

To understand the use and installation of busways for an interior wiring system.

INTRODUCTION:

Busway is one of the newer developments in interior wiring systems. It provides a flexible power distribution system for industrial plants and school shops for motors and in some cases, lights. This method provides for the connecting branch motor circuits to the mains readily and economically when machines are rearranged. The system has a wide use in industrial plants where the layout of the machines must be continually changed in order to meet changing manufacturing conditions. The first cost may be somewhat greater than for other methods of wiring, but the savings derived from its flexibility in the relocation of machines without additional wiring expense soon overbalances the additional first cost. With the flexible busway method of wiring there is no ripping out and scrapping of old materials and installing new materials to meet the new layout conditions. Busway may be installed in exposed dry locations for circuits of not more than 600 volts.

Busways consist of bus bars mounted in a sheet metal enclosure or trough. They are made in three main types for voltage up to 600 volts:

(1) Without plug-in provision
(2) With plug-in provision at fixed intervals
(3) With movable trolley contacts

Busways of over 600 volts are also available for use in special applications.

NOTE: If it is possible, visit a busway installation.

APPLICATION:

Have the students answer the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

CABLEBUS

DESIRED RESULTS:

To become acquainted with the Code requirements when installing cablebus.

INTRODUCTION:

Cablebus is an approved assembly of insulated conductors mounted in a ventilated metal structure. Cablebus is generally assembled at the point of installation, from components furnished or specified by the manufacturer. These conductors are mounted in a good space relationship to each other. Cablebus may be used at any voltage or current for which the spaced conductors are rated. It may be installed only for exposed work.

DISCUSSION QUESTIONS:

1. Discuss the types, ampacity, size and number, and supports for conductors.
2. What overcurrent devices are used with cablebus?
3. How should cablebus conductors be supported?
4. What fittings are used in the cablebus system?
5. Discuss the terminations, grounding, and marking of the cablebus.

APPLICATION:

Have the students complete the questions for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

SWITCHES

DESIRED RESULTS:

To become acquainted with the Code requirements concerning the installation and construction specifications of switches.

INTRODUCTION:

Any switch should open all ungrounded conductors of the circuit. In no case may a single-pole switch be placed in the grounded conductor. Number of poles required for switches to control three common types of circuits: (1) 2-wire single phase or D.C. circuit with one conductor grounded, (2) 3-wire single phase or D.C. circuit with grounded neutral, and (3) 4-wire three-phase circuit with grounded neutral.

Opening only the grounded wire of a two-wire circuit would leave all devices that are connected to the circuit alive. The voltage to the ground would equal the voltage between the wires on the mains. In case of an accidental ground on the grounded wire, the circuit would not be controlled by the single-pole switch.

Lamps that are connected between the neutral and the two or three outer wires of the 3-wire and 4-wire circuits are not balanced. If the neutral is then opened, it would cause the voltages to become unbalanced and might burn out all lamps on the more lightly loaded side. In any case a switch may be arranged to open the grounded conductor if it simultaneously opens all the other conductors of the circuit. Since three-way and four-way switches are actually single-pole switches they must not be used to disconnect the grounded circuit wire, because this would be a violation of section 380-1.

A metal switch plate, if not grounded, may become "alive" by reason of contact of the ungrounded circuit wire with the plate or switch box. A hazard is thus created if the plate is within reach from any conductive object. The hazard still exists, however, if a plate of insulating material is attached by means of metal screws with exposed heads.

RATING OF SNAP SWITCHES:

a. For a noninductive load not including any tungsten-filament lamps, a snap switch is merely required to have an ampere rating at least equal to the ampere rating of the load it controls. Electrically heated appliances are common examples of such loads.

b. For the control of loads consisting of tungsten lamps alone, and for combined tungsten-filament with any other noninductive load, snap switches should be T rated. Thus T rated switches are required in all public spaces, such as hotel lobbies, retail stores, and places of assembly.

c. Inductive loads which are commonly controlled by snap switches are fluorescent lamps, mercury-vapor lamps, and gas-tube signs and lighting. The term "snap switch" as used here and elsewhere in the Code is the common types of flush and surface-mounted switches. They are used for the control of lighting equipment and small appliances and are generally the tumbler or toggle type switch.

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

SWITCHBOARDS AND PANELBOARDS

DESIRED RESULTS:

To study the requirements of the Code that apply to switchboards, panelboards, and distribution boards installed for the control of light and power circuits.

INTRODUCTION AND DISCUSSION:

A switchboard as defined by the Code is a large single panel, frame, or assembly of panels, on which are mounted, on the face or back or both, switches, overcurrent and other protective devices, busses, and usually instruments.

It is difficult to define panelboard and switchboard in such a way as to make a clear-cut distinction between the two. A panelboard with its enclosing cabinet is sometimes called a panel box. Panel boxes may be of either the flush or surface type. Surface type boxes are used for installations employing exposed wiring. The boxes are generally constructed of sheet metal, which must not be less than No. 16 U. S. Standard Gage in thickness. Gutters are provided around the panelboards in panel boxes in order to allow sufficient space for wiring.

Accessibility and working space are very necessary to avoid shock hazards and to provide easy access for maintenance, repair, operation, and housekeeping. It is preferable to increase the minimum space behind a switchboard to at least 36 inches where space will permit.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

HIGH VOLTAGE EQUIPMENT AND INSTALLATION

DESIRED RESULTS:

1. To understand the general scope of this article as it applies to all circuits and equipment operated at more than 600 volts.

2. To study the provisions applicable to specific types of installations covered in other articles.

INTRODUCTION:

It is recommended that you review the articles listed in the reference sheet concerned with wiring installations and methods involved. Wiring methods that are to be used to install conductors above ground and underground should be reviewed.

The installation of equipment, indoor and outdoor work, should be given special attention. Also, much of the equipment has special provisions and instructions listed by the manufacturer. Note that some states do not have these requirements and also many states have specific requirements that are not included with the equipment. Who pays the bill for special or added materials used on the job to make installations?

Instructors should continue to search for a better way of presenting the articles of the Code. Try to make it interesting with illustrations from your experience.

PRESENTING THE LESSON:

Present the scope of this article, installations covered in other articles, wiring methods, equipment (general and special provisions), etc.

Installation of high voltage equipment is accessible to Qualified Persons Only. Present some of the "Kinks of the Electrical Trade" in the methods of installing this equipment.

APPLICATION:

Have the students complete the worksheet on the lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

THEATERS AND ASSEMBLY HALLS

DESIRED RESULTS:

To become acquainted with the requirements of the Code concerning the wiring methods and the use of portable electrical equipment in theaters and like buildings used for public assembly.

INTRODUCTION AND PRESENTATION:

The requirements of Article 520 shall apply to all buildings or part of a building used for dramatic, motion-picture or other shows, and public auditoriums. The motion-picture projectors and associated equipment shall comply with Article 540. The sound-reproducing equipment and its installation shall comply with Article 640.

Where only a part of a building is used as a theater, auditorium, or place of public assembly, these special requirements apply only to that part and do not necessarily apply to the entire building. A common example is a school building in which there is an auditorium used for dramatic or other performances. All special requirements of Article 520 would apply to the auditorium, stage, dressing rooms, projection room, sound reproduction equipment, and the main corridors leading to the auditorium. Other parts of the school building that do not pertain to the use of the auditorium are not controlled by this article.

Building laws usually require theaters and motion-picture houses to be of fireproof construction. Thus, most of the buildings are wired for light and power with rigid conduit and electrical metallic tubing. Small auditoriums are the exception.

Much of the stage lighting in a modern theater is provided by floodlights and projectors mounted in the ceiling or on the balcony front. In order that the projectors can be adjustable in position, they may be connected by plugs and short cords to suitable receptacle. The term gallery receptacles should include all receptacles, wherever they can be located, that are intended for the connection of stage lighting equipment. Circuits to such receptacles must be contolled at the stage switchboard where other stage lighting circuits are controlled.

A stage switchboard must have no live parts on the front, and the back must be guarded to keep all unauthorized persons away from it. The more important stage switchboards are of the remote-control type. Pilot switches mounted on the stage board control the operation of

contactors installed usually below the stage. The stage switchboard is generally built into a recess in the wall. After passing through the switches and dimmers, many of the main circuits must be subdivided into branch circuits so that no circuit will be loaded to more than 20 amperes.

Modern type footlights are mounted in the face of a sheet metal trough construction containing the circuit conductors. Each lamp is provided with an individual reflector and glass color screen. Footlights of the disappearing type should be arranged so that the current supply will be automatically disconnected when they are placed in the recess.

Border lights are usually hung on steel cables so that their height can be adjusted in order that they can be lowered to the stage for cleaning and replacing lamps and color screens. The circuit conductors supplying the lamps must be carried to the border through a flexible cable.

Portable stage equipment, lanterns, or similar devices are likely to be made of paper or other inflammable material. The lamps used in this equipment and in dressing rooms should be provided with guards that cannot be removed to prevent them from coming in contact with flammable material.

APPLICATION:

Have the students complete the worksheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

COMMUNICATION CIRCUITS

DESIRED RESULTS:

To become acquainted with the provisions of the Code as they apply to telephone, telegraph (except radio), district messenger, fire and burglar alarms and similar central station systems.

INTRODUCTION AND DISCUSSION:

A. General: The following sections of this chapter on communication systems apply only to those systems which are connected to a central station and operate as parts of a central station system.

B. Protection: A protector approved for the purpose should be provided on each circuit, aerial or underground. They shall be located in or on the building as near as practicable to where the conductors enter. The conductors should not come in contact with light or power conductors operating at a potential exceeding 300 volts. The protector should not be located in any hazardous location, nor near easily ignitable materials. The protector should be mounted on a noncombustible insulating base, consisting of an arrestor, a ground, and a fuse in each live conductor. A protector without fuses can be used under conditions described in Article 800.

C. Outside conductors:
   1. Where overhead communication conductors and light or power conductors are supported by the same pole
      a. They should be located below the light and power conductors
      b. They should not be attached to a cross arm which carries light or power conductors.
      c. Ample climbing space is needed in order to avoid danger to the linemen.
   2. Conductors passing over buildings should be at least 8 feet above any roof, except small auxiliary buildings.
   3. Circuits which require protectors shall comply with the Code.
      a. Each conductor should have 1/32-inch rubber insulation.
      b. Conductors within a cable of metal-sheathed type conduit should have 1/32-inch rubber insulation, and should be covered with a substantial fibrous material.
      c. On buildings, open conductors should be separated at least 4 inches from light and power conductors not in a conduit or cable. They should be placed on insulating supports.
      d. The conductors should enter the building through an insulating bushing or metal raceway, where the protector is installed inside.

D. Underground circuits:

1. Underground communication conductors in a duct or manhole containing electric light and power conductors should be separated by means of brick, concrete, or tile partitions.
2. Where the entire circuit is run underground, the circuit within the block is placed as to be free from liability of accidental contact with electric light or power circuits.

E. Grounding:
Equipment should be grounded as follows:
1. The metal sheath of aerial cables entering buildings should be grounded.
2. The protector ground should comply with the following:
   a. The grounding conductor should have 1/32-inch rubber insulation.
   b. The conductor should not be smaller than No. 18 copper wire.
   c. The grounding conductor should be run in as straight a line as practicable to the grounding electrode.
   d. The grounding electrode should be guarded from physical damage.
   e. The grounding conductor should preferably be connected to a water pipe electrode.
   f. The conductor should be attached to a pipe electrode by means of a bolted clamp to which the conductor is connected.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

RADIO AND TELEVISION EQUIPMENT

DESIRED RESULTS:

To become acquainted with the requirements of the Code concerning radio and television receiving equipment, and amateur radio transmitting and receiving equipment.

INTRODUCTION:

For service drops and conductors on the exterior of buildings, the requirements for insulating covering and methods of installation depend upon the liability of crosses occurring between the signal conductors and the light or power conductors. Where communication wires are run on poles in streets, it is assumed that they are exposed to contact with other wires; 1/32-inch insulation is required. Where the overhead wires are run in an alley or from building to building and kept away from streets, lighter weight insulation is permitted. Some communication systems are connected to a distribution system that is entirely underground except within the block in which the building is located. Any overhead wires in alleys or attached to buildings are not liable to become crossed with light and power wires. The restrictions as to insulating covering and methods of installation are eliminated.

Lead-in conductors for antenna systems should have adequate strength and corrosion resistant qualities. In the event that a broken wire might come in contact with a light or power wire, this will ensure continuity of service. It is important that all possible precautions be taken to prevent the possibility of a cross between a radio antenna and a light or power conductor.

Most of the antennas for television reception that are supported on metal structures must be grounded to protect them from lightning. Grounding must be done in accordance with the Code, Article 250. It is good practice to use the same ground electrode for the grounding of masts as is used for the electrical system of the building.

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

DATA PROCESSING EQUIPMENT

DESIRED RESULTS:

1. To become acquainted with the equipment, power supply wiring, equipment interconnecting wiring and grounding of data processing systems.

2. To study the code to understand the three methods of connecting data processing systems.

INTRODUCTION:

The provisions of this Article shall apply to equipment, power supply wiring, equipment interconnecting wiring, and grounding of the data processing systems including data communications equipment used as a terminal unit.

PRESENTING THE LESSON:

1. Give the scope and definitions needed.
2. Review the code concerning supply circuits and interconnecting cables.
3. Discuss the disconnecting means:
   a. In Data Processing rooms
   b. In general building areas
4. Refer to the grounding in accordance with Article 250
5. Markings
   a. Manufacturers nameplate
   b. Items to be listed on nameplate are rating in volts, the operating frequency, and the total load in amperes.

APPLICATION:

The student should complete the worksheets.

CHECKING AND FOLLOW-UP:

Check the papers.

LOW VOLTAGE SYSTEMS

DESIRED RESULTS:

To study the provisions of the Code that apply to low voltage systems, such as remote-control circuits, low-voltage relay switching, low energy power circuits, low voltage circuits and signal circuits.

INTRODUCTION:

The provisions of this Article are not intended to apply to remote-control, low-energy or signal circuits which form an integral part of a device or appliance.

Circuits or equipment coming within the scope of this Article and installed in hazardous locations shall also comply with appropriate provisions of Articles 500 through 517.

PRESENTING THE LESSON:

This Article 725 is divided into the following parts:

A. Scope and General
B. Class I System
C. Limitations of Low-voltage Power Circuit
D. Class II System Voltage and Current Limits
E. Installation of Class II Remote-Control and Signal Circuits

Discuss the significant aspects of each section of the Article 725.

APPLICATION:

The students should complete the worksheet for this assignment.

CHECKING AND FOLLOW-UP:

Check the answers.

ANALYSIS OF CONTROL CIRCUITS

DESIRED RESULTS:

1. To be able to analyze circuits developed by someone else.
2. To be able to understand as much as possible about the operation of the machine which the motor drives so that the function of the circuit can be analyzed.
3. To be able to make schematic drawings properly in order to help analyze the circuits.

INTRODUCTION:

The student who wishes to obtain proficiency in analysis of control circuits must be able to apply the basic principles to other circuits that are at his disposal. He should practice with these circuits until he is satisfied that he can, with reasonable speed, interpret and analyze control circuits of all types.

The danger in circuit analysis work lies in the tendency to jump at conclusions. The worker will decide what the circuit does and how it operates when he has checked only a part of its possibilities. He should learn to study a circuit, contact by contact and coil by coil, until he has analyzed it from beginning to end.

PRESENTING THE LESSON:

The basic procedure for circuit analysis is very simple and should be readily understood if the student has mastered the material on control circuit development. The learner should consider the circuit one part at a time and decide what happens if a contact closes or opens a circuit. When relays are used in the circuit, he should be sure that each contact which is closed or opened by that relay is considered. When analyzing a circuit, he should be sure that every component in its normal and energized positions is checked out so that the entire circuit is understood.

APPLICATION:

Have the students complete the Assignment Sheet for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

MAINTAINING CONTROL EQUIPMENT

DESIRED RESULTS:

1. To acquaint the apprentice with some of the basic principles of good maintenance.

2. To teach that preventative maintenance is inspecting, cleaning, and keeping the control equipment tight and not repairing.

INTRODUCTION:

This lesson should point up some of the basic principles of good maintenance. The actual maintenance of a specific piece of equipment must be determined by its operating cycle, complexity of its components, and the time available for this care. Maintenance means to maintain the equipment in operating condition as compared with repairing the equipment after it has broken down.

One of the greatest causes of failure of control systems is dust, grease, oil, and dirt, which should be removed at regular intervals. This is called preventative maintenance. There should be scheduled inspection dates to prevent serious breakdowns.

There is a single rule which applies to all electrical maintenance work and under all conditions. The rule is be careful. Carelessness and failure to observe electrical safety rules are two bad habits maintenance men cannot afford.

PRESENTING THE LESSON:

I. The first procedure in any organized maintenance of equipment program should be periodic inspection.

   A. Remove dust, grease, oil, and dirt with a solvent. Provide adequate ventilation.
   B. Check for excess heat of bearings, coils, contacts, and transformers.
   C. Lubricate bearings of motors and mechanical equipment.
   D. Check for loose bolts and nuts on electrical connections and on the equipment.
   E. Use a megger insulation tester on motors and cables.

II. There are two laws to follow in preventative maintenance:

   A. Know your equipment mechanically and electrically so that you can sense trouble before it develops.

B. Be observant. Whenever you pass a piece of equipment for which you are responsible, inspect it.

NOTE --
Good maintenance can be summed up in the following words: Keep it tight, keep it clean, keep it lubricated, and inspect it frequently.

III. Call attention to the maintenance of the following equipment:

A. Motor starters and causes of trouble
   1. Improper adjustment of contacts and time-delay circuits
   2. Coil burnout
      a. Failure of the contactor magnet circuit to close
      b. Improper voltage

B. Relays
   Maintenance essentially same as motor starter and contactors

C. Pilot devices
   Check mechanical operation and contact condition

D. Brakes and clutches
   1. Replace worn brake lining
   2. Wear and improper adjustment of linkage

APPLICATION:

Have the students complete the Assignment Sheet questions for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

TROUBLESHOOTING CONTROL CIRCUITS

DESIRED RESULTS:

1. To determine the section of the control circuit that contains the trouble.

2. To select the proper component or simple branch to be checked.

INTRODUCTION:

Some men who can do an excellent job of wiring from a circuit diagram are lost if the circuit fails to function. The secret of efficient and accurate troubleshooting lies in determining the section of the control circuit that contains the trouble component and then selecting the proper component to be checked. This can be accomplished by efficient and accurate circuit analysis, not by trial and error.

GENERAL PROCEDURE:

The first procedure should be to analyze the circuit to determine whether or not it has been properly designed and installed. The next step is to follow the operation of the equipment through the expected sequence until the section of the circuit which is not properly operating is found. It should be a simple procedure to check the wiring and operation of the components involved in this section of the circuit and correct the trouble.

TROUBLESHOOTING AN EXISTING CIRCUIT:

The first step in troubleshooting an existing circuit which has developed trouble is to understand the circuit and the operation of the machine it controls. With the help of the operator, the machine can be followed through its cycles until it reaches the point where it does not function properly. A careful check of this circuit will generally lead to the source of the trouble. The first step is to locate the components involved in this part of the circuit. There must be a coil of a relay, a contactor, or some other device which is energized by this section. The machine should be run through its sequence to determine if this coil receives energy and if the contactor or relay does not close as it should. The circuit should be disconnected and the wires removed from the coil of the relay or contactor so that a voltage check can be taken. If the voltmeter indicates the proper voltage has been applied, then the trouble may be in the windings of the coil itself.

CHECKING PROCEDURE:

If it is believed that the coil is at fault, disconnect the power and use an ohmmeter to check the resistance of the coil. If the coil is burned out, there will be a high resistance reading, or a reading of infinity on the ohmmeter.

If the voltage check showed that the voltage did not reach the coil when it should in the sequence of operation of the control circuit, this indicates that some contact is not closing when it should or is coated with copper oxide or other insulating material. The other possibility is an open circuit caused by a broken or burnt wire. This is the least likely cause of trouble. Having checked the contacts and eliminated the trouble, proceed to the next section of the control which does not function.

The above procedure is based on years of experience and an understanding of the fact that control circuits are made up of only two things:

(1) Contacts which make and break the circuit.
(2) Coils which operate these contacts.

The most important rule in troubleshooting is to change only one thing at a time. Try the circuit again before changing anything else.

The best equipment for efficient and proper troubleshooting of individual components is a complete knowledge of their proper operation and a familiarity with as many manufacturers' versions of each component as possible. No matter how complex the control circuit, the efficient troubleshooter will narrow his trouble down to one of the simple branches.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

PRINCIPLES OF STATIC CONTROL

DESIRED RESULTS:

1. To understand the meaning of static control and to learn to read static control or logic diagrams.

2. To understand the basic functions and the parts of a static control system.

INTRODUCTION:

In previous lessons the language of control by relays and moving contact has been discussed. Now it is necessary to convert this language into one that will apply to static control ideas. The language of static control and its circuit requirements are expressed in terms of logic functions. Until recently, this type of control was limited in use to automation in plants. However, it appears that most single machines are using static control as part of their built-in system. Static control is the term used to define a system of machine or process control which uses no moving parts or electrical contacts.

PRESENTING THE LESSON:

I. Elements of static control

A. The four logic elements are and, not, or, and memory. Typical symbols for these elements are shown in Figure 10-1 of the text. Basically, these logic functions are fulfilled by the four logic elements and a time delay. Any explanation of the control of a machine can be expressed in terms of the logic relationships of each function.
   1. Present logic element symbols (Figure 10-1)
   2. Discuss inputs and outputs
   3. Show the progressive steps in designing a circuit
      a. Use Figures 10-2, 10-3, 10-4, and 10-5
      b. Use Figures 10-6, 10-7, and 10-8

II. Why static control

A. The subject of control can be broken down into three parts: Information, decision, and action
   1. Information
      a. Sensing devices

(1) Limit switches, push buttons, pressure switches temperature sensors

2. Decision or "brains"
   Assimilate and correlate
3. Action
   a. Solenoid value
   b. Contactor or starter
   c. Indicating light

Static control seems to be the best method of achieving the three main objectives we have discussed. Magnetic amplifiers and other static devices have in common a characteristic of operation which is basically different than that of relays. This difference is that static devices may have one or more inputs and a single output. Relays, have a single input to the coil and one or more outputs, depending on the number of contacts used. A different approach is employed in designing control systems using static devices. The computer specialists faced this problem when they had to convey information using vacuum tubes. They devised a way of assimilating information and arriving at decisions by a system of logic functions. They showed that all intelligence could be broken down into five basic logic functions, each having one or more inputs and a single output.

III. Theory of Logic Function

A. The first function is and
B. The second logic function is the or
C. The third logic function is not
D. The fourth function is memory
E. The fifth function is delay

IV. Application of static elements

A. Trace the development of the desired operating cycle requirements to control a planer table. Use reference figures and illustrations in the text.
   1. Step 1 - Planer-table circuit
   2. Step 2 - Planer-table circuit
   3. Planer-table circuit, complete

APPLICATION:

Have the students complete the problems and questions for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

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TRANSISTORS AS LOGIC ELEMENTS

DESIRED RESULTS:

1. To acquaint the students with the use of transistorized logic elements in custom-designed circuitry.

2. To illustrate the use of transistors and diodes as found in logic circuitry.

INTRODUCTION:

The third static control system we shall discuss is one using transistorized logic elements in custom design circuitry. The transistor is the latest and newest of the relay type control devices. It is defined as a three element semiconductor amplifying device. The three elements are called the collector, base, and emitter named from their functions. Invented in 1948, the transistor is mechanically strong, compact, cheap, and long-lived. Operation is very fast, comparable in speed for control purposes with vacuum tubes. Currently available transistors will handle 20 to 50 volts and new ones up to 450 volts. Thus, the logic part of the control circuit uses transistors, but the final closure of the power circuit to the motor must use a relay or contractor.

PRESENTING THE LESSON:

1. In order that the student understand the logic circuit, discuss some basic facts of transistors and the proper handling of them.

2. Discuss how transistors may be ruined by certain incorrect electrical conditions.
   a. Over voltage
   b. High temperature
   c. Wrong polarity of collector voltage

3. Consider several elementary transistor circuits using drawings in Figures 12-5 and 12-6a or others.

4. Discuss amplifier action in transistors by referring to Figure 12-6b and 12-6c or others.

5. Consider the transistor in some possible logic circuits. Refer to Figure 12-7, Figure 12-8, and others.

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

BASIC THEORY OF ELECTRONICS

DESIRED RESULTS:

To acquaint the apprentice with the basic theory of electronics from the standpoint of industrial control circuits.

INTRODUCTION:

We think of electricity as the flow of electrons in or on a conductor or through a gas or space as in a vacuum tube. We think of electronics as a science which deals with the use, characteristics, and properties of electrons, especially in vacuum tubes. Practical electronics deals with the electron tube itself, with its ability to amplify, rectify, and detect, as well as with the components and circuitry associated with it.

The industrial applications of electronics include timing circuits, photoelectric counting and measuring, theater light dimming, motor control, resistance and arc welding, and many others.

Daily we come in contact with common place electronic equipment which use vacuum tubes, such as: radio, sound motion pictures, record players, public address systems, television, and electric eye door openers. The above equipment also makes use of various types of D.C. and A.C. circuits, meters, transformers, capacitors, resistors, and other components studied in basic electricity.

The apprentice will probably have his greatest contact with industrial electronics on the job in the form of controls and instrumentation. The equipment used in this field will consist of a power supply, an amplifier, some form of sensing device, and an output device. In working with these devices, it is difficult to distinguish between electricity and electronics.

PRESENTING THE LESSON:

1. Discuss the three basic electronic circuits:
   a. Rectifier circuits
   b. Amplifier circuits
   c. Oscillator circuits

2. Explain the use of six types of parts in the circuits:
   a. Resistors
   b. Capacitors
   c. Induction coil
   d. Transformer
   e. Switch
   f. Vacuum tubes

3. Show how a diode tube works:
   a. Using drawings show the electron emission from the cathode
   b. Demonstrate the diode D C circuit with current flow
   c. Show the effect of plate voltage on current flow
   d. Show saturation in the diode tube
   e. Demonstrate the diode A C circuit with current flow (rectification)
   f. What is a half wave rectifier circuit?
   g. What is a full wave rectifier circuit?

4. Discuss and note the following points:
   a. The electron flow within the tube
   b. The difference in current flow for A C and D C circuits

APPLICATION:

Have the students complete the questions on the Assignment Sheet.

CHECKING AND FOLLOW-UP:

Check the answers.

INFORMATION SHEET LESSON D-24

BASIC THEORY OF ELECTRONICS

1. The electrician thinks of current in terms of amperes and considers one or two amperes as a very low current. In electronics, we deal with current in milliamperes, and consider one or two amperes to be a very high current.

2. The electrician considers A C voltage at the consumer location as 110, 220, or 440 volts. In electronics voltage is generally D C and often ranges from 300 to 1,000 volts. In this study, we will learn to deal with composite voltages, there will be voltages made up of both D C and A C components.

3. We think of power being measured in watts or kilowatts. In electronics, most power requirements are very small, such as, milliwatts (1/1000).

The three statements above do not change the basic laws of electricity but require us to apply the things we know to new situations. Other than the semi-conductor field of electronics, there are only six components commonly used. All six of these components have been studied and now you must apply their use to vacuum tubes.

SWITCHES:

Mechanical devices for completing, interrupting, or changing the connections in an electric circuit.

CIRCUIT:

The electrician works with many types of circuits or paths over which an electric current flows, such as lighting, motor control, etc. There are unlimited variations of the lighting circuit, and there are unlimited variations of the electronic circuits, such as the amplifier circuits. The student that masters the basic circuit will have no real problem with the variations.

COILS:

You are familiar with coils used in motor starters. There is no difference in those coils and the coils used in electronics, except the physical design.

RESISTORS:

A resistor has a power-handling rating from one hundred to several thousand watts. The demands of the circuit in which they are used determines the size. Electronic resistors are specified in ohms or megohms or 1/2 watt or less to 100 watts. The demands of the circuit will determine the size and resistance requirements.

CAPACITORS:

In studying motors, you found that capacitors were used in starting motors and for power factor correction.

Electronic capacitors in radio circuits are used to block the flow of direct current while allowing alternating and pulsating currents to pass. They are rated in microfarads and micro-microfarads.

TRANSFORMERS:

We think of a transformer as a device that transfers electrical energy by electromagnetic induction from one or more circuits to one or more other circuits. It is measured in high voltage and reduces this voltage to usable voltage.

The transformers used in electronics are generally built for specific jobs handling low power at radio frequency. The principles of the large transformer apply to the radio and other electronic devices.

Now, let us consider the new component introduced in this lesson, the vacuum tube. This device involves some new concepts of electricity which you must learn. In use, it acts like either a variable resistor or a switch, or both depending upon the circuit in which it is used. The main advantage of the vacuum tube is the speed with which it can vary its resistance and turn on or off in response to external signals.

You have learned the theory of electron flow in metallic conductors used in electrical work. It was the flow of free electrons from a negative potential to a positive potential through a conductor that contains free electrons.

Now, let us consider the flow of free electrons through a vacuum or gas. The electron flow is caused by the attraction of unlike charges and the repulsion of like charges. Remember that the flow of current in a vacuum is very small as compared to the flow through a metallic conductor under the same potential. When the proper gas is added to a tube the current flow is increased by a process known as ionization. This will create completely different characteristics for specified uses.

The semi-conductors offer some new concepts in electricity which we must accept and apply in order to understand their use. Semi-conductors are a class of solid materials with high resistance qualities. Another group, more important in communications, are semimetallic elements or oxides in which conductivity is electronic. Semi-conductors are used as rectifiers, detectors, and amplifiers in transistors and thermoelectric elements.

The apprentice will contact industrial electronics on the job in the form of controls and instrumentation. The equipment used in this field will consist of a power supply, an amplifier, and some form of sensing device, and an output device. In working with these devices, it will be difficult to distinguish between electricity and electronics.

WELDERS, RESISTORS, AND RECTIFIERS

DESIRED RESULTS:

1. To study the electric welding processes, how the welders can be controlled by electronics, and code requirements for electric welding equipment connected to an electric power supply.
2. To learn the function of resistors and rectifiers in control circuits.

INTRODUCTION:

This Article covers electric arc welding, resistance welding apparatus, and other similar welding equipment that is connected to an electrical supply system.

It is the intent of this Article to amplify or modify parts of the Code in order to properly cover the operating conditions to which electric welder installations are subjected. Accordingly, the appropriate provisions of Chapters 1 through 4 inclusive apply to component parts of electric welder installations except as otherwise provided in this Article.

The control of resistance welders by electronic methods is one of the oldest and most common applications of electronics to the industrial world. Review with the students the basic circuits studied earlier and welding equipment that is connected to an electrical supply according to the code. The circuits used in the welder are special adaptions of the basic circuits.

When resistance welding takes place, high currents of electricity are caused to flow through two pieces of metal. These pieces of metal are held together under pressure by welding electrodes, which are chosen for high electrical and thermal conductivity. A standard electrode material is copper. The disadvantage of using copper is that the electrode tip becomes deformed rapidly. When higher pressure and temperatures are necessary, a hard copper alloy is used. Most machines use circulating water to cool the electrodes. Thus, they select the electrode made of materials containing high electrical and thermal conductivity. This method keeps the temperature low and prevents the electrodes from being welded to the material.

PRESENTING THE LESSON:

1. Discuss the capacity of supply conductors and overcurrent protection for individual welders.

2. Review the general types of welders to be installed and their varying operations.

3. What disconnecting means should be provided for each welder?

4. What information shall be provided on a nameplate?

5. What are the factors that determine the amount of heat produced by a given welding current?

6. What is the range of voltage generally applied to a weld in resistance welding?

7. What keeps the electrodes from being welded to the materials being welded?

8. What is spot welding? Name other classes of welding.

9. List the four steps that are timed or controlled by electronic controls on a resistance welder.

10. In the diagram shown in Figure 8-5, list four components that determine the welding time. What function does each part play?

11. Discuss the use of synchronous control over non-synchronous control.

12. Refer to Figure 8-9 electrostatic welding system. How is the weld produced?

13. Refer to Figure 8-10 magnetic inductor storage welding system. How is the voltage produced for the weld?

14. In Figure 8-11, discuss the basic arc welding control circuit. What determines how quickly or slowly the welding electrode is to be moved toward the work?

15. Discuss the use of resistors and rectifiers in control circuits.

APPLICATION:

Have the students complete the assignment questions for this lesson.

CHECKING AND FOLLOW-UP:

Check the answers.

INSTRUCTOR'S MANUAL
AND
INFORMATION SHEET

LESSON D-26

LESSON PLAN OUTLINE

TOPICS: Job Management and Effective Foremanship

DESIRED RESULTS:

1. To explain the roles of job management and effective foremanship if and when one is promoted.
2. To develop leadership qualities and discuss how the new manager adjusts to his job.
3. To give the students experience in planning, conducting, and evaluating a class on conference session.
4. To teach the "art of listening" for those not engaged in presenting materials.

INTRODUCTION:

The instructor should introduce and help plan the sessions several weeks before the scheduled meetings. The students should research on the subject and meet with a committee to plan the sessions.

PRESENTING THE LESSON:

The committee should choose the type of presentation such as role playing, case study, or circular discussion.

The printed outline of an instructor's lesson plan, along with information sheets, should help in planning the sessions.

1. Review the job management sheets and the effective foremanship from the student outlines.
2. Point out that the following leadership qualities will be developed by participating in these sessions.
   a. Ability to express oneself
   b. Analyze and solve daily work problems
   c. Analytical attitude toward all problems

CLASS DISCUSSION

JOB MANAGEMENT

DISCUSSION OUTLINE:

1. What you manage
   a. Yourself
   b. Your helper
   c. Tools and equipment
   d. Time and materials

2. How you manage
   a. "Bull-of-the-woods"--phasing out--replaced by
   b. Leader
   c. Instructor
   d. Paper-work man

3. Why you manage
   a. Every job must have some management
   b. Increase efficiency
   c. Lower costs
   d. Improve profit margin

4. When you manage
   a. Before job starts
   b. During job
   c. After completion of job
   d. "Off duty" hours--planning and layout

5. Where you manage
   a. On the job
   b. Personal life
   c. Community life

FOLLOW THESE TWELVE RULES IF YOU'RE PROMOTED TO A MANAGEMENT JOB

(A. J. Drucker, Manager of the Management Development Center in IBM's Data Processing Division suggests:)

1. Don't get personally involved when something doesn't seem to be turning out right. (Help your subordinates find a solution.)

2. Talk less and listen more.

3. Make sure your door is open to your associates. You can't learn everything from written reports.

4. Remember that what motivated you may not motivate your subordinates. (Find out what makes each man tick and apply it accordingly.)

5. Set out to help your men develop their greatest potential. (You also will be judged on how well you perform this job.)

6. Adopt a positive attitude in performing the administrative detail your job requires. (How well you handle it will figure importantly in any estimate of your future potential.)

7. Don't shy away from decisions in the early months. Your judgments must have been good so far or you wouldn't have been promoted. (So don't be afraid of making them.)

8. Think management. You are the company; its policies are your policies. (So don't apologize for any headquarters' action. If you do, you will weaken your authority.)

9. Don't always support the old and familiar. (Give a fair hearing to new ideas.)

10. Gradually moderate your former close relationships with subordinates.

11. Don't tolerate mediocrity. (Your subordinates want to meet a high standard.)

12. Work harder than ever.

MANAGEMENT SHOULD ELIMINATE COMPLAINTS ABOUT CONFERENCES

According to research on business meetings conducted by a manufacturer, the corporate officer or supervisor errs in one or more of three ways:

1. He calls a meeting without any real reason. The subject could have just as easily been resolved by a telephone call.

2. He calls a meeting at the drop of a hat. (Nobody has a chance to prepare, gather facts, or do any advanced thinking and nothing is achieved.)

3. He may not conduct the meeting well; it gets underway late, is interrupted by telephone calls and secretaries, and discussions become untracked resulting in no decisions.

You'll do better following these simple tips:

1. Never call a meeting if you can write or phone--or either delegate the job or do it yourself.

2. Invite only those persons who are directly concerned with the matter at hand.

3. Always tell them ahead of time what topics will be covered and give them time to prepare.

4. Start on time, end on time, and don't permit any interruptions.

INFORMATION SHEET LESSON D-27

EFFECTIVE FOREMANSHIP

DISCUSSION OUTLINE:

1. Where foremen come from

2. Why are they selected
   a. Leadership qualities
   b. Organizational ability
   c. Mechanical skill
   d. Technical skill
   e. Judgment
   f. Initiative
   g. Education
   h. Character
   i. Human interest
   j. Physical and mental ability

3. Foreman's training
   a. Starts at childhood
   b. Develops as he grows
   c. Improves as he progresses
   d. Always something new to learn
   e. No "guaranteed course" with all the answers

4. Half of the job almost done
   a. Apprentice training
      (1) On-the-job
      (2) Related technical training
   b. Your education in general
   c. Your life's experiences
   d. Your association with other people

5. The other half of the job
   a. Skills of leadership
   b. Methods of personnel supervision
   c. Development of sound administrative procedures
   d. Improving on-the-job performance